Particle "Precipitation" in the Thermosphere / Ionosphere

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What “Precipitation” Affects the Thermosphere/Ionosphere

pre•cip•i•ta•tion |priˌsipəˈtā SH ən|
noun
1 Chemistry the action or process of precipitating a substance from a solution.
2 rain, snow, sleet, or hail that falls to the ground.
3 archaic the fact or quality of acting suddenly and rashly : *Cora was already regretting her precipitation.*

ORIGIN late Middle English (denoting the action of falling or throwing down): from Latin ***praecipitatio(n-)***, from ***praecipitare ‘throw down or headlong’*** (see PRECIPITATE).

Primarily auroral electrons in the energy range 100 eV – 100 keV
...also protons and other ions in the energy range 1 keV – 1 MeV

Radiation belt particles, Solar energetic particles, cosmic rays, etc., are of little importance above ~90 km, because they pass right through the thermosphere.

“I got no kick against the east coast; you know the people there have got the most; and New York City’s like a friendly ghost, you seem to pass right through...” — Bob Segar, Katmandu.

Outline of Presentation

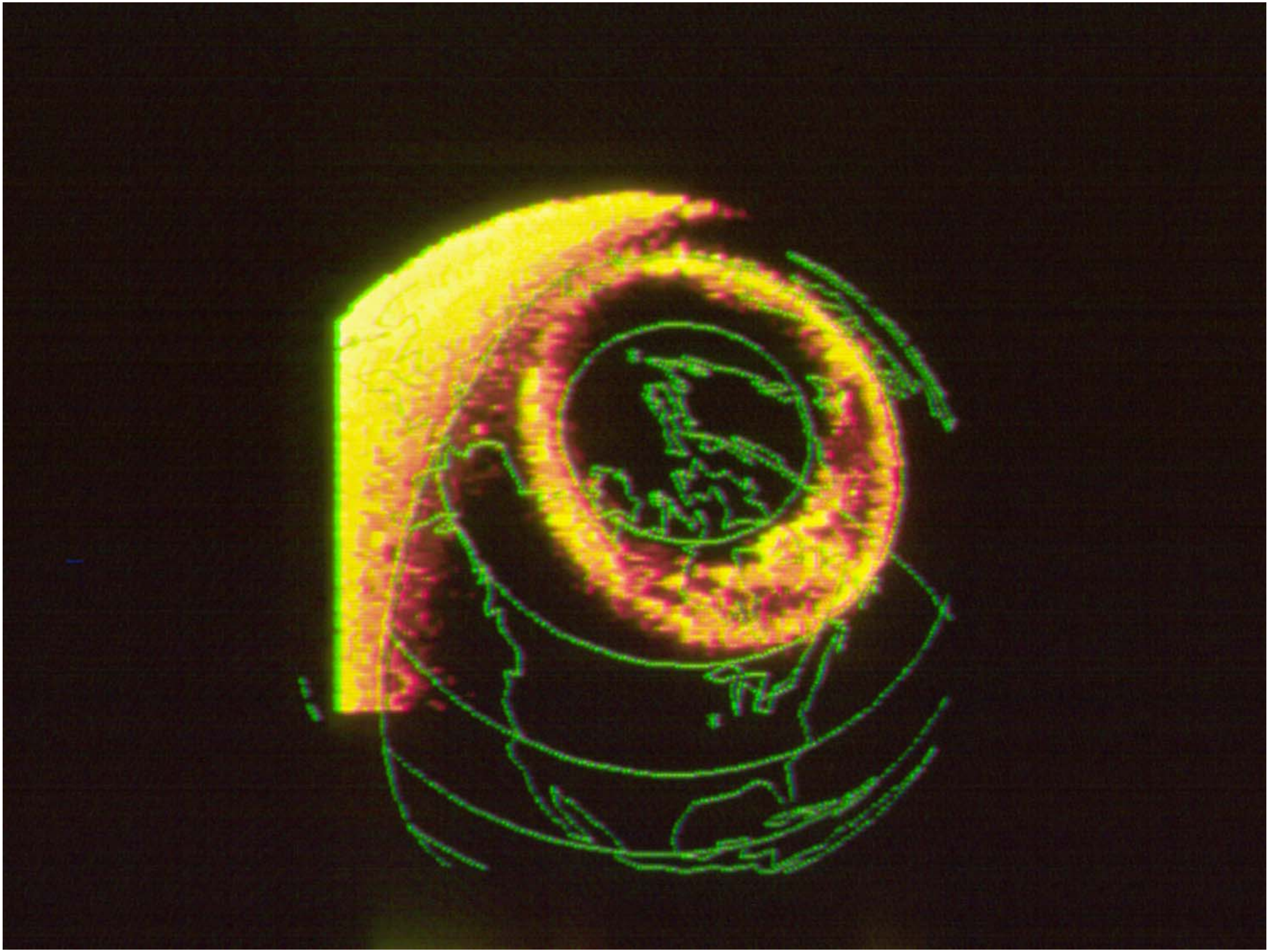
- Simple tutorial on auroral energy deposition and thermosphere/ionosphere effects
- Introduction to the odd-nitrogen problem and the sources of nitric oxide
- Integrated auroral power and the magnitude of the chemical response

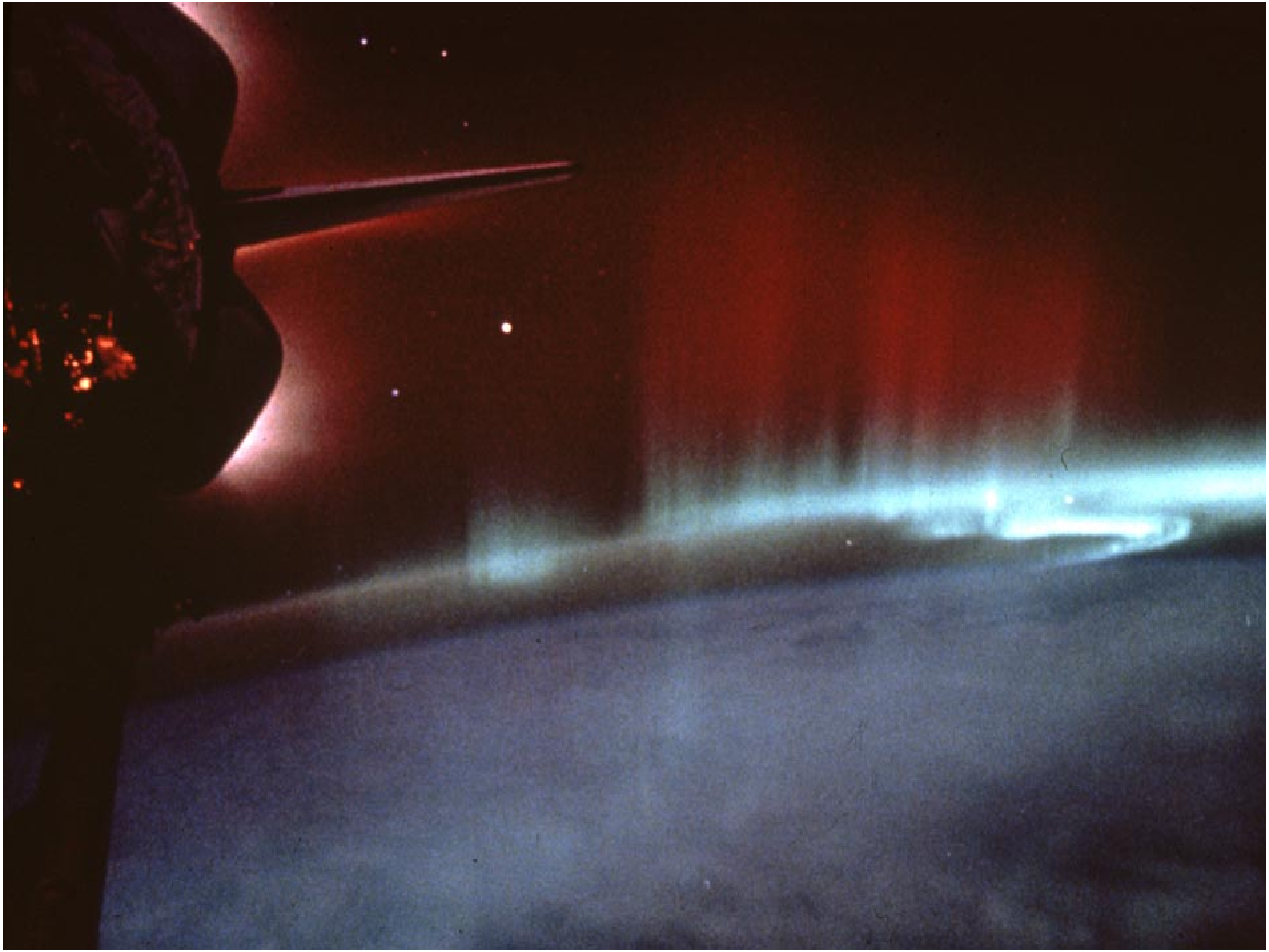
...not going to talk about:

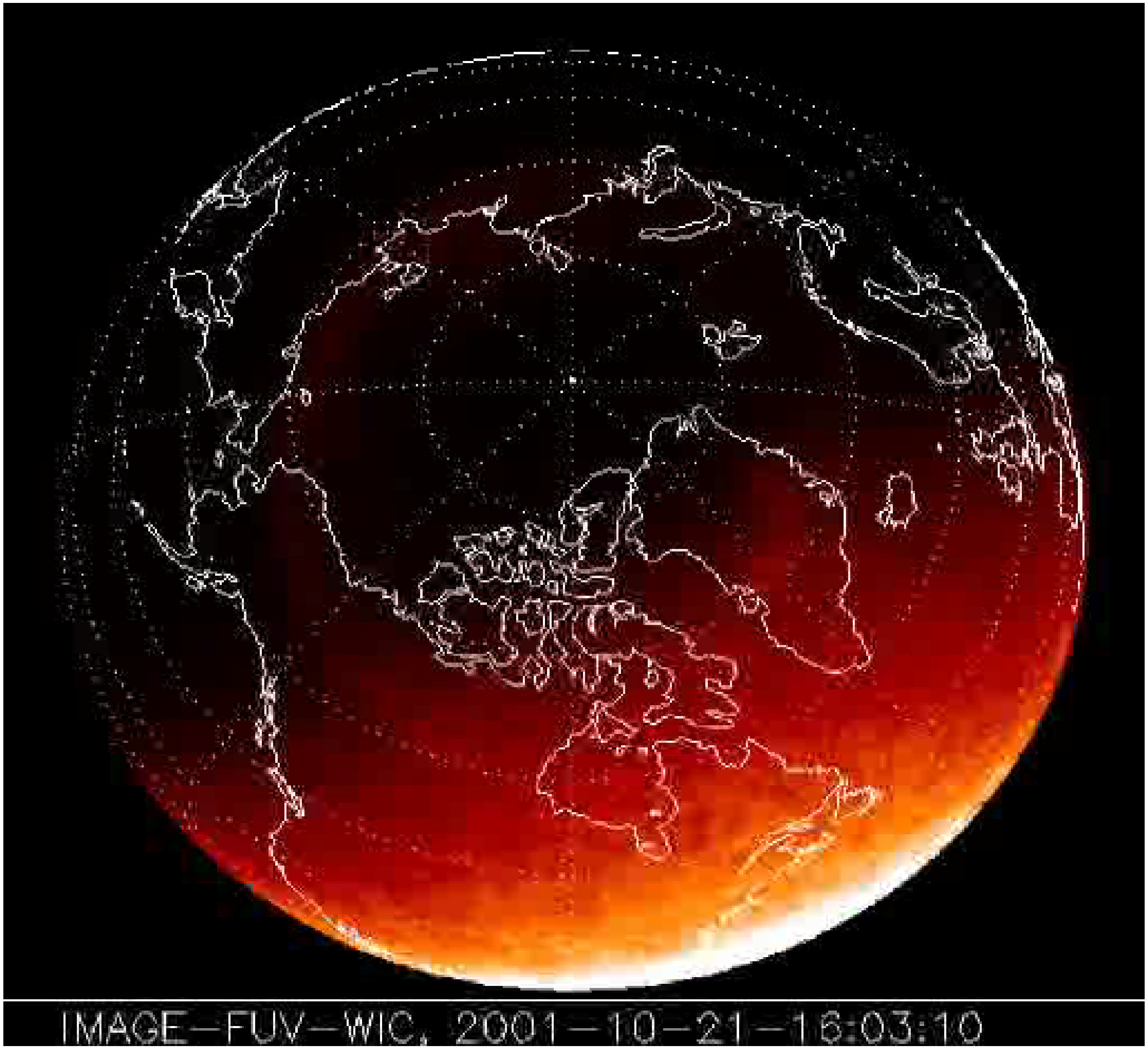
— electrodynamical coupling and Joule heating

— disruption of the ionospheric electric field

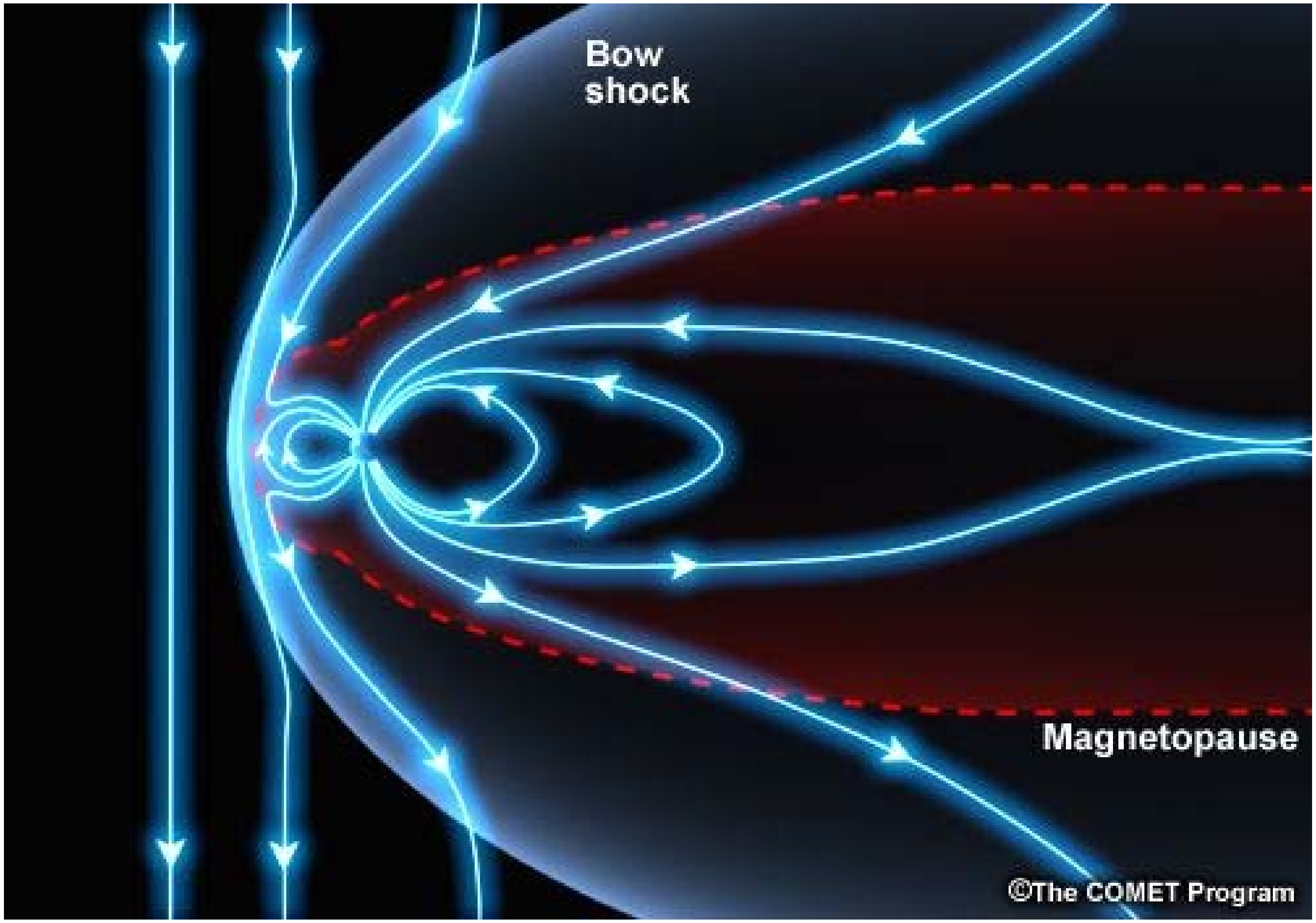
— response of thermospheric temperature, density, and wind



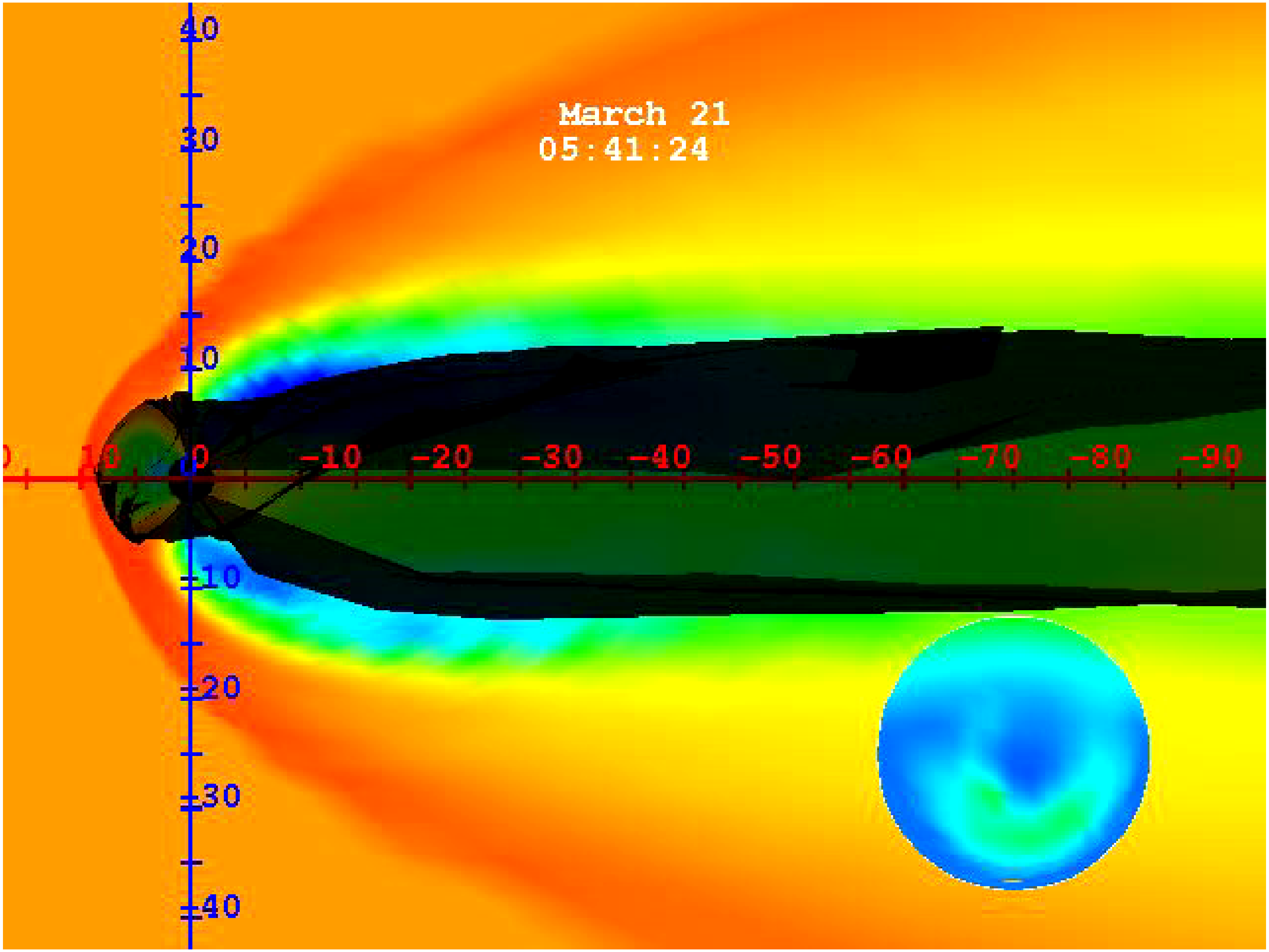



IMAGE–FUV–WIC, 2001–10–21–16:03:10

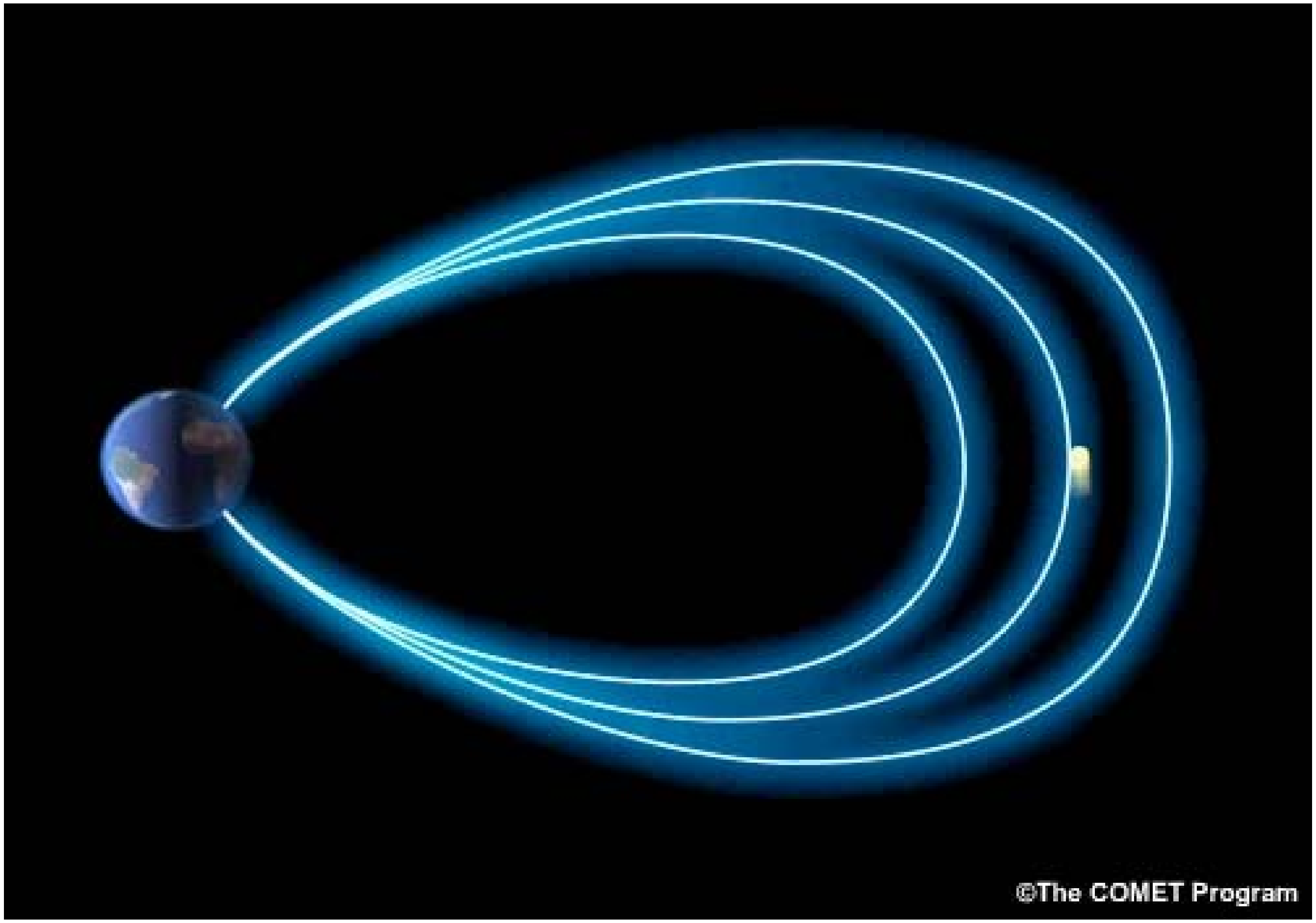
Reconnection in the Magnetotail



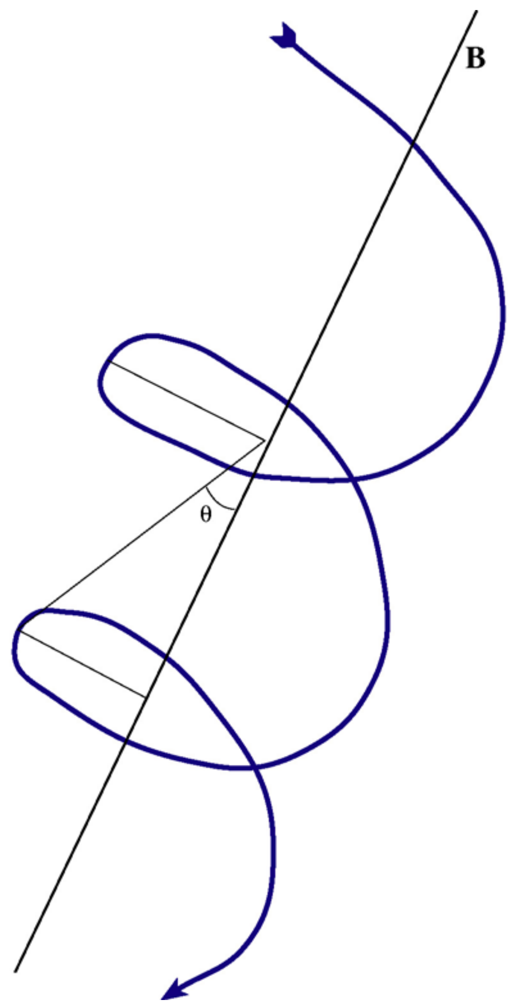
Coupled Magnetosphere-Ionosphere-Thermosphere Model



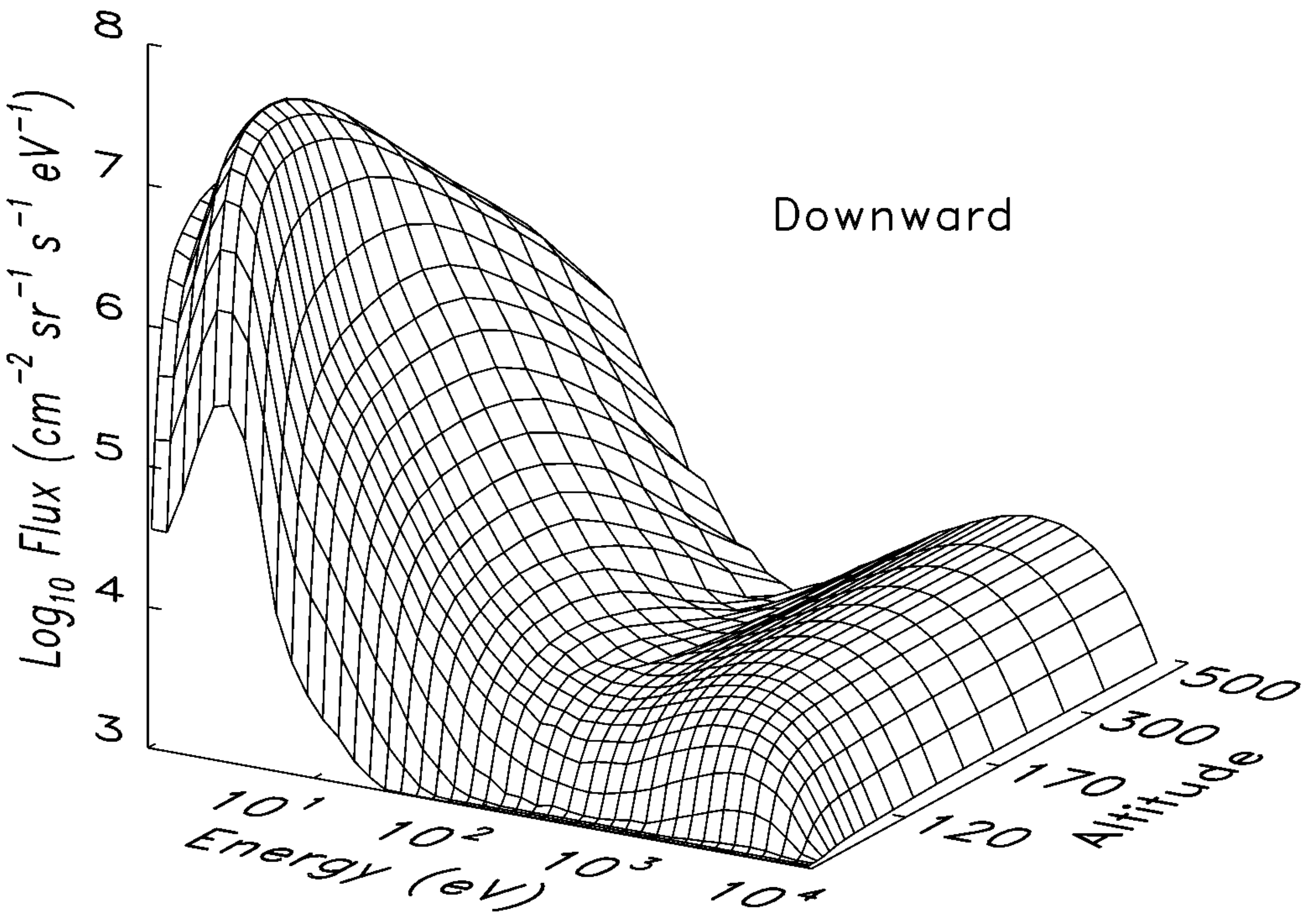
Energetic Particles from the Magnetosphere



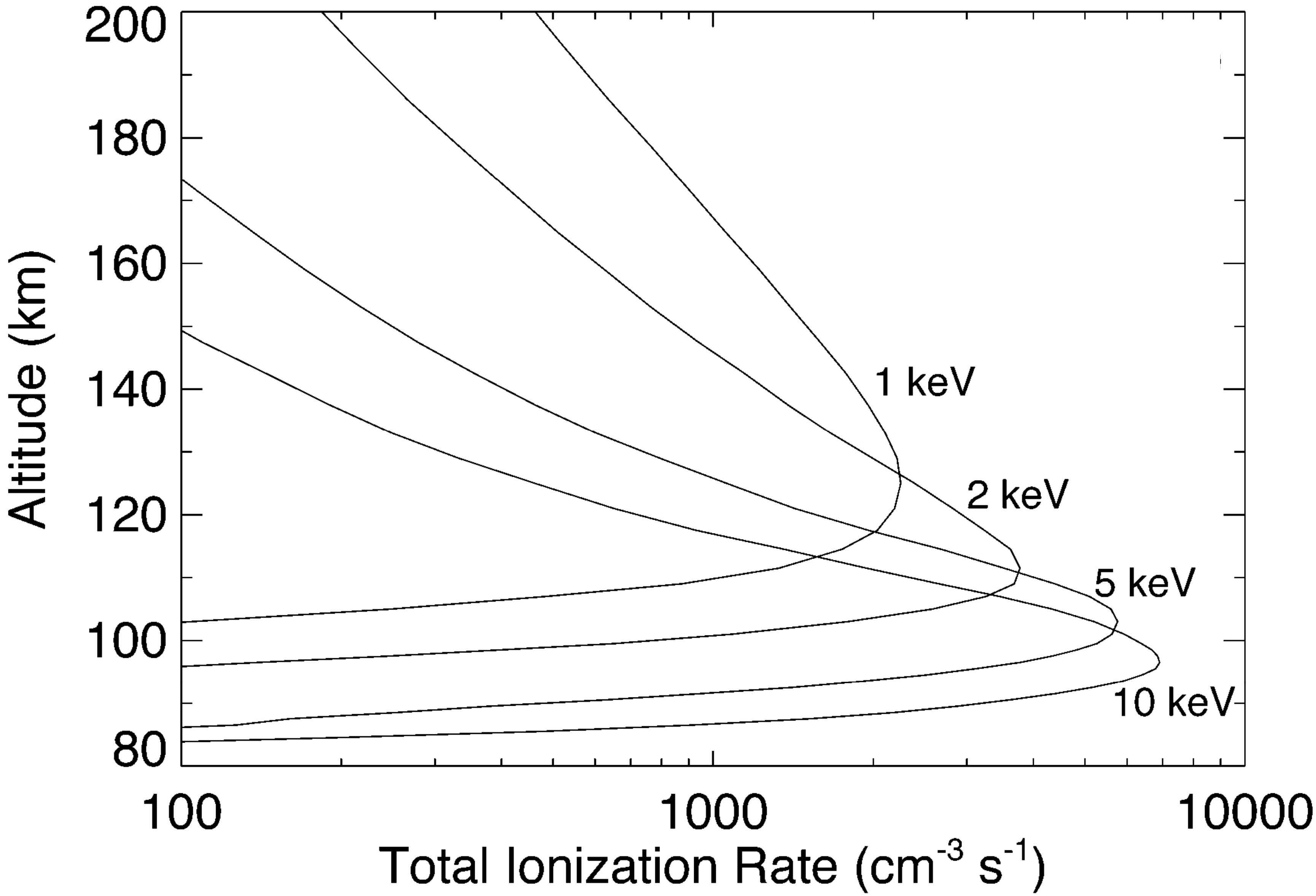
Motion of Charged Particles Along a Magnetic Field Line



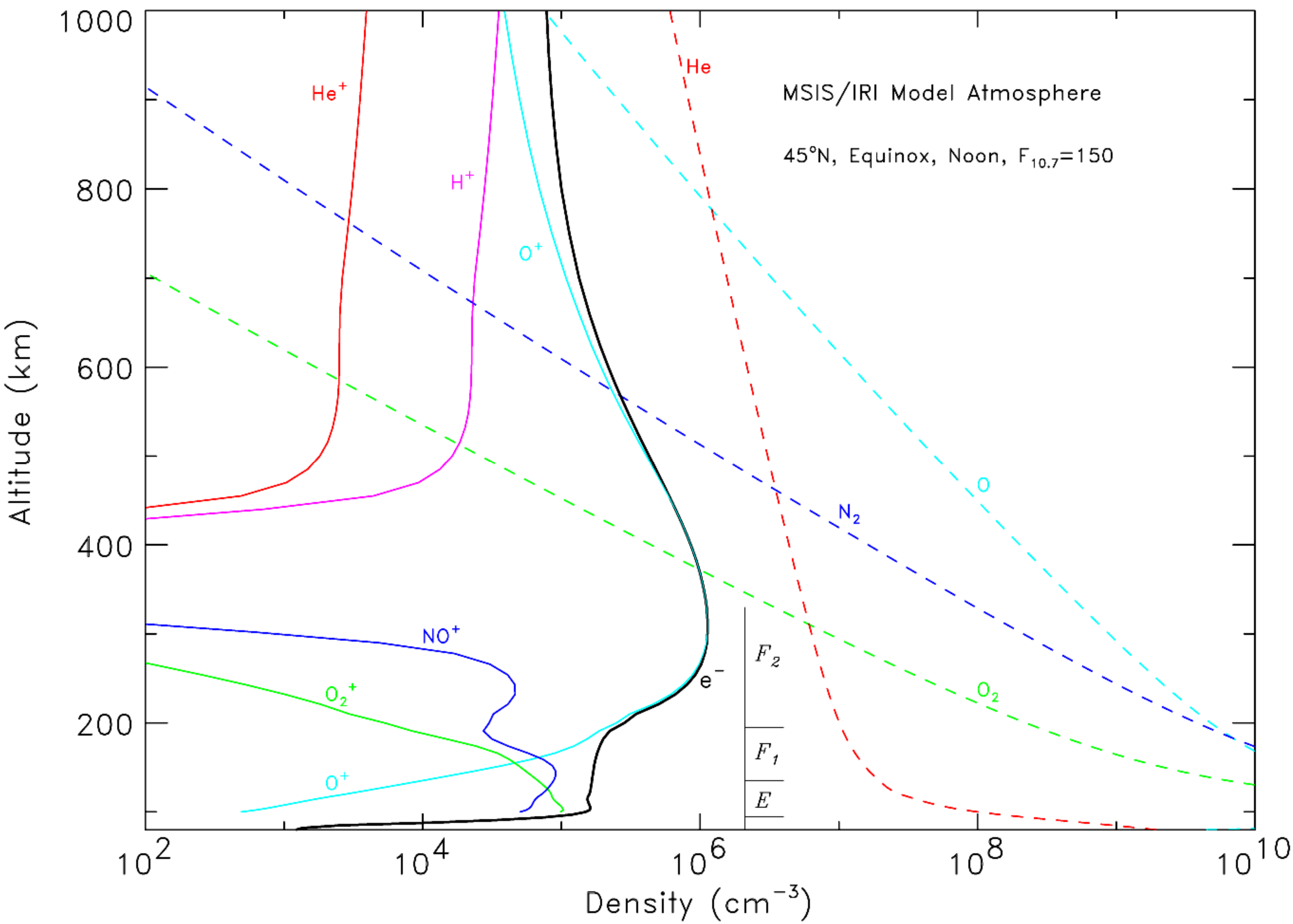
Transport of Auroral Electrons in the Upper Atmosphere



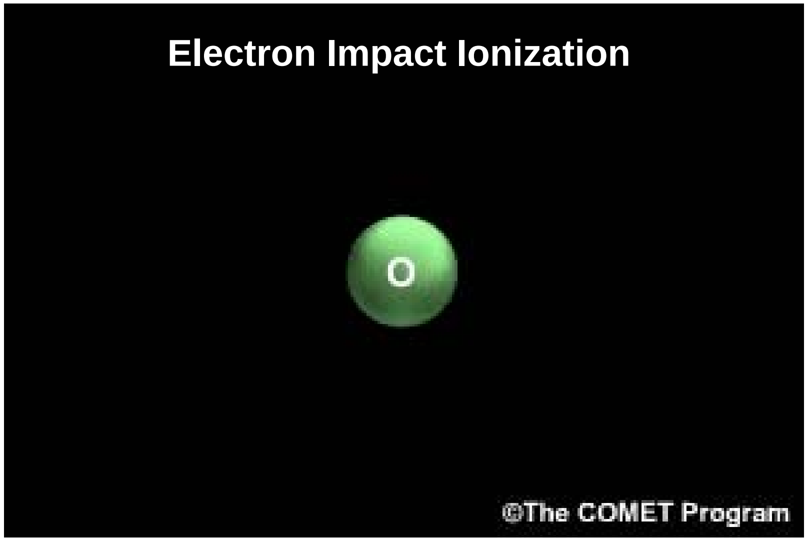
Penetration Depth of Auroral Electrons Depends on Energy

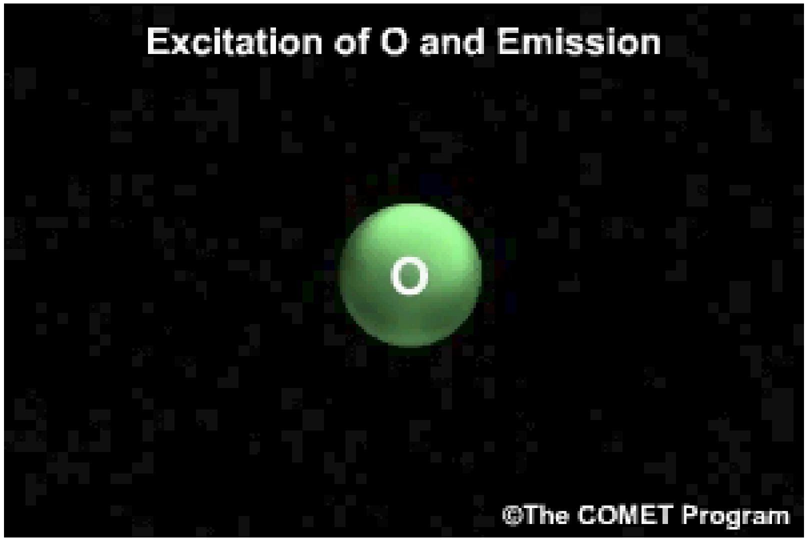


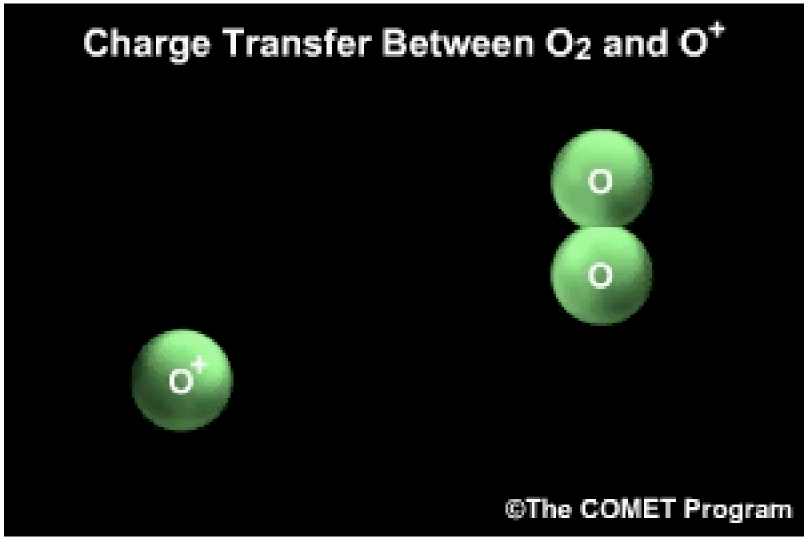
Thermosphere and Ionosphere Composition

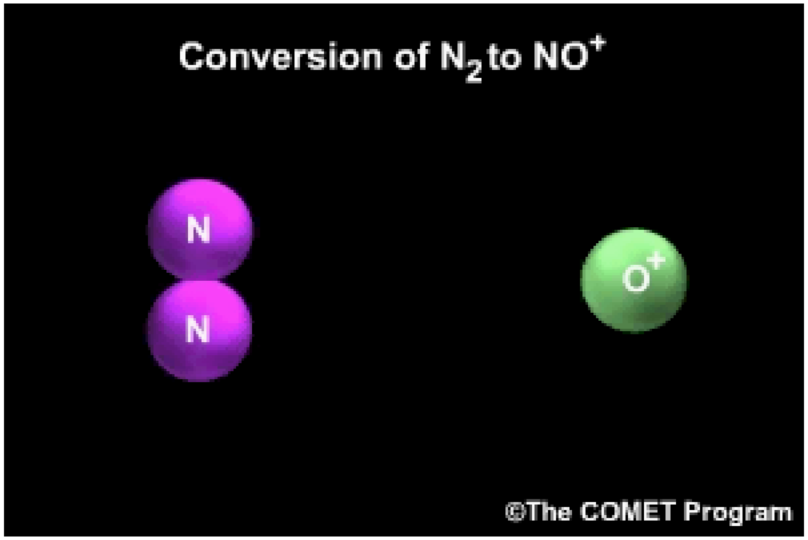


Auroral Collisional Processes

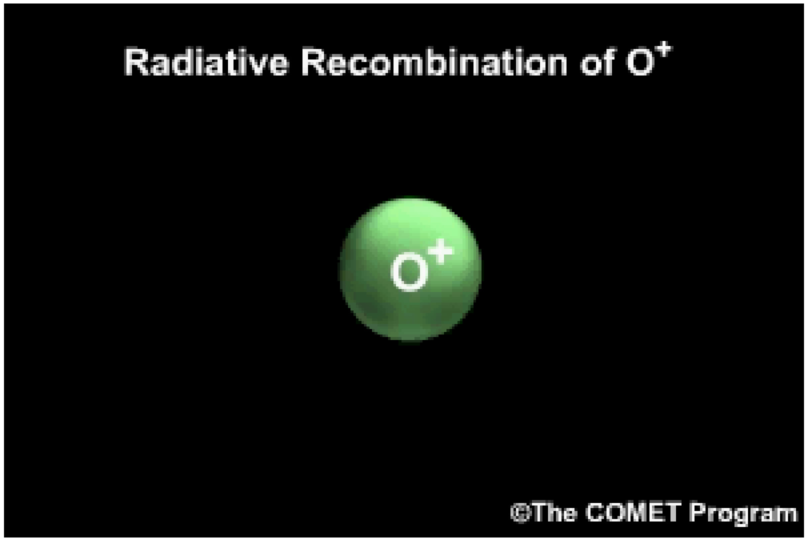


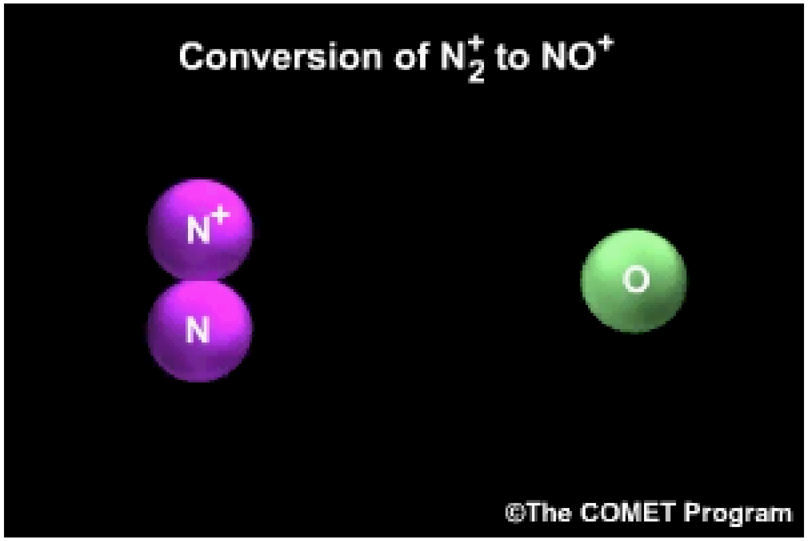


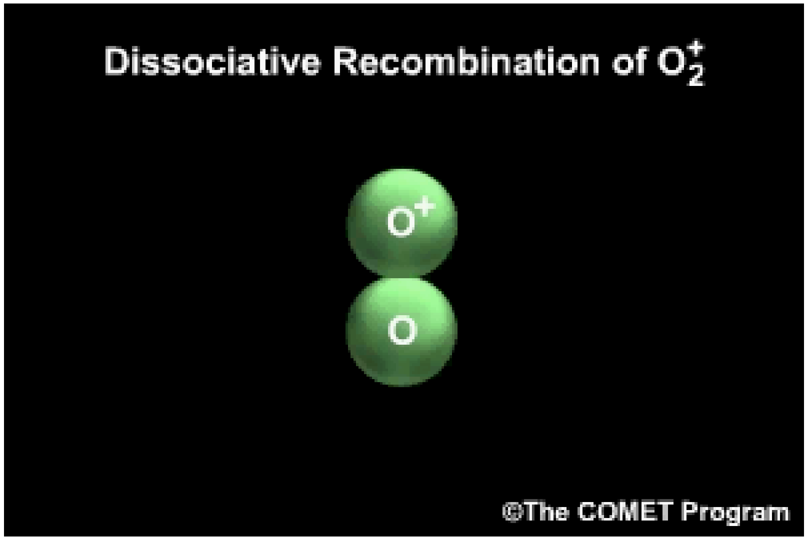


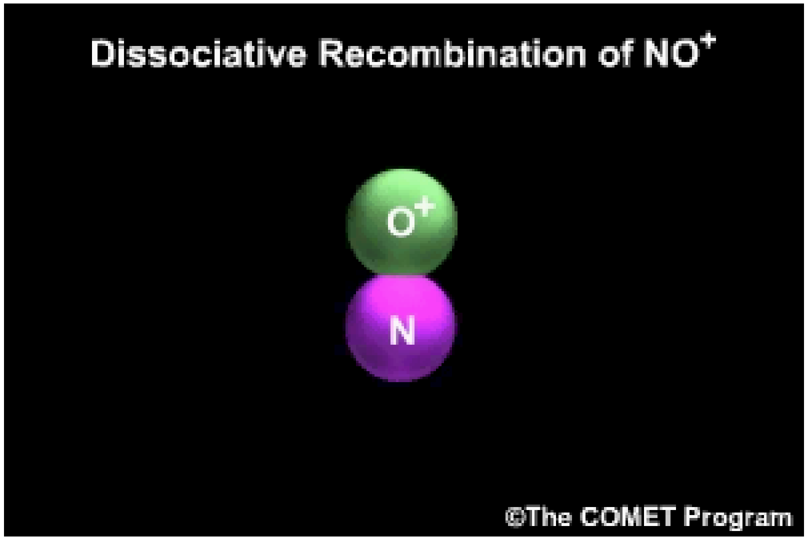


Ion Recombination Processes









Examples of Auroral Emission Processes

Molecular Nitrogen:

$e^* + N_2 \rightarrow 2e^* + N_2^+(B^2\Sigma_u^+)$ $N_2^+(B^2\Sigma_u^+) \rightarrow N_2^+(X^1\Sigma_g^+) + h\nu$ (1N bands)

$e^* + N_2 \rightarrow e^* + N_2(B^3\Pi_g)$ $N_2(B^3\Pi_g) \rightarrow N_2(X^1\Sigma_g^+) + h\nu$ (1P bands)

$e^* + N_2 \rightarrow e^* + N_2(A^3\Sigma_u^+)$ $N_2\,(A^3\Sigma_u^+) \rightarrow N_2(X^1\Sigma_g^+) + h\nu$ (VK bands)

$N_2\,(A^3\Sigma_u^+) + O(^3P) \rightarrow N_2(X^1\Sigma_g^+) + O(^1S)$

$O(^1S) \rightarrow O(^3P) + h\nu$ (5577Å)

Examples of Auroral Emission Processes

Atomic Oxygen:

$e^* + N_2 \rightarrow e^* + N_2(A^3\Sigma_u^+)$ $\quad$ $N_2\,(A^3\Sigma_u^+) + O(^3P) \rightarrow N_2(X^1\Sigma_g^+) + O(^1S)$

$O(^1S) \rightarrow O(^3P) + h\nu$ $\quad$ (5577Å) $_{\tau\sim 1s}$

$e^* + O(^3P) \rightarrow e^* + O(^1S)$ $\quad$ $O(^1S) \rightarrow O(^3P) + h\nu$ $\quad$ (5577Å) $_{\tau\sim 1s}$

$e^* + O(^3P) \rightarrow e^* + O(^1D)$ $\quad$ $O(^1D) \rightarrow O(^3P) + h\nu$ $\quad$ (6300Å) $_{\tau\sim 100s}$

$O_2^+ + e^- \rightarrow O + O(^1D)$ $\quad$ $O(^1D) \rightarrow O(^3P) + h\nu$ $\quad$ (6300Å) $_{\tau\sim 100s}$

$O(^1D) + N_2 \rightarrow O(^3P) + N_2$

Examples of Auroral Emission Processes

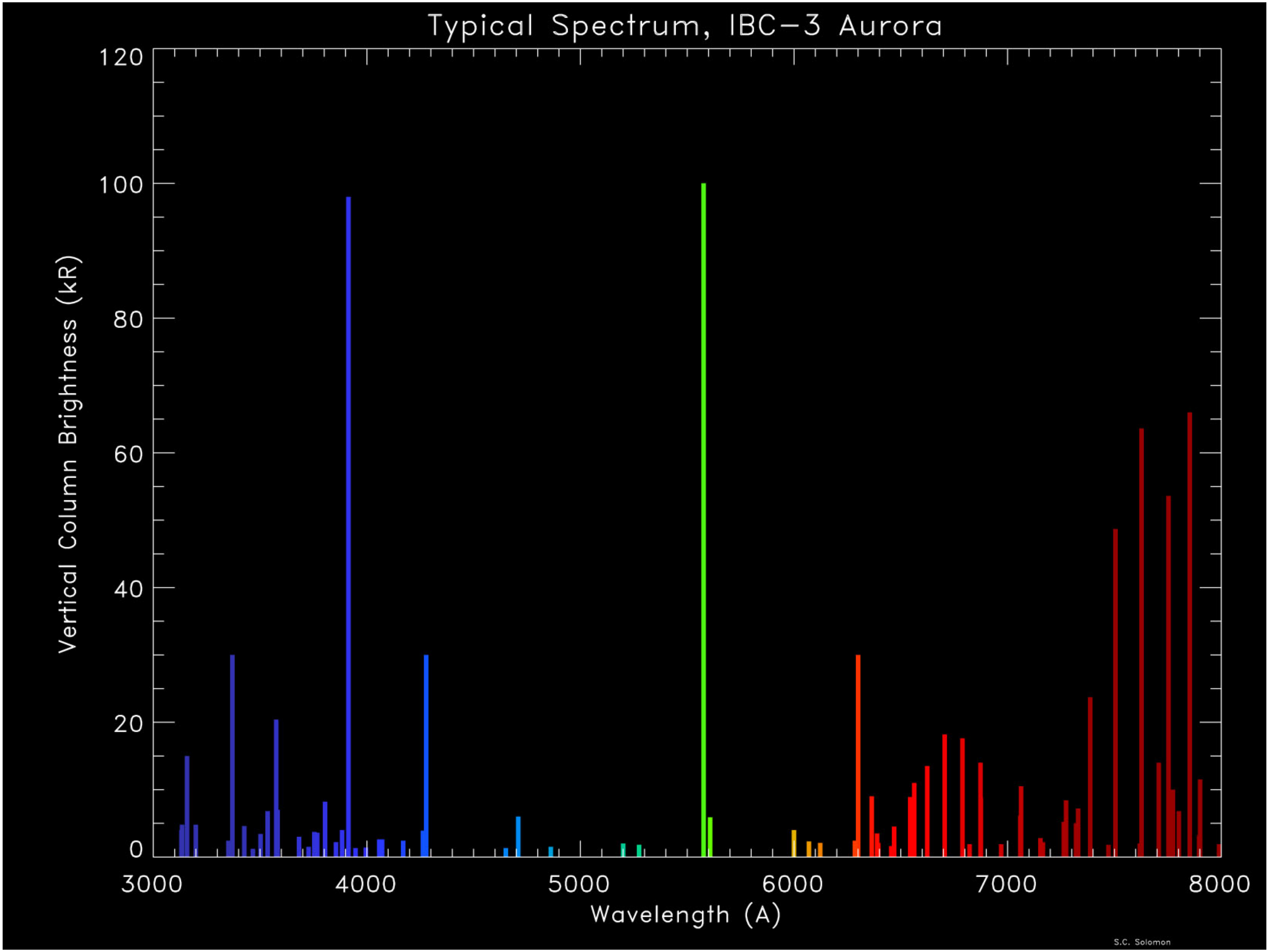
Atomic Nitrogen:

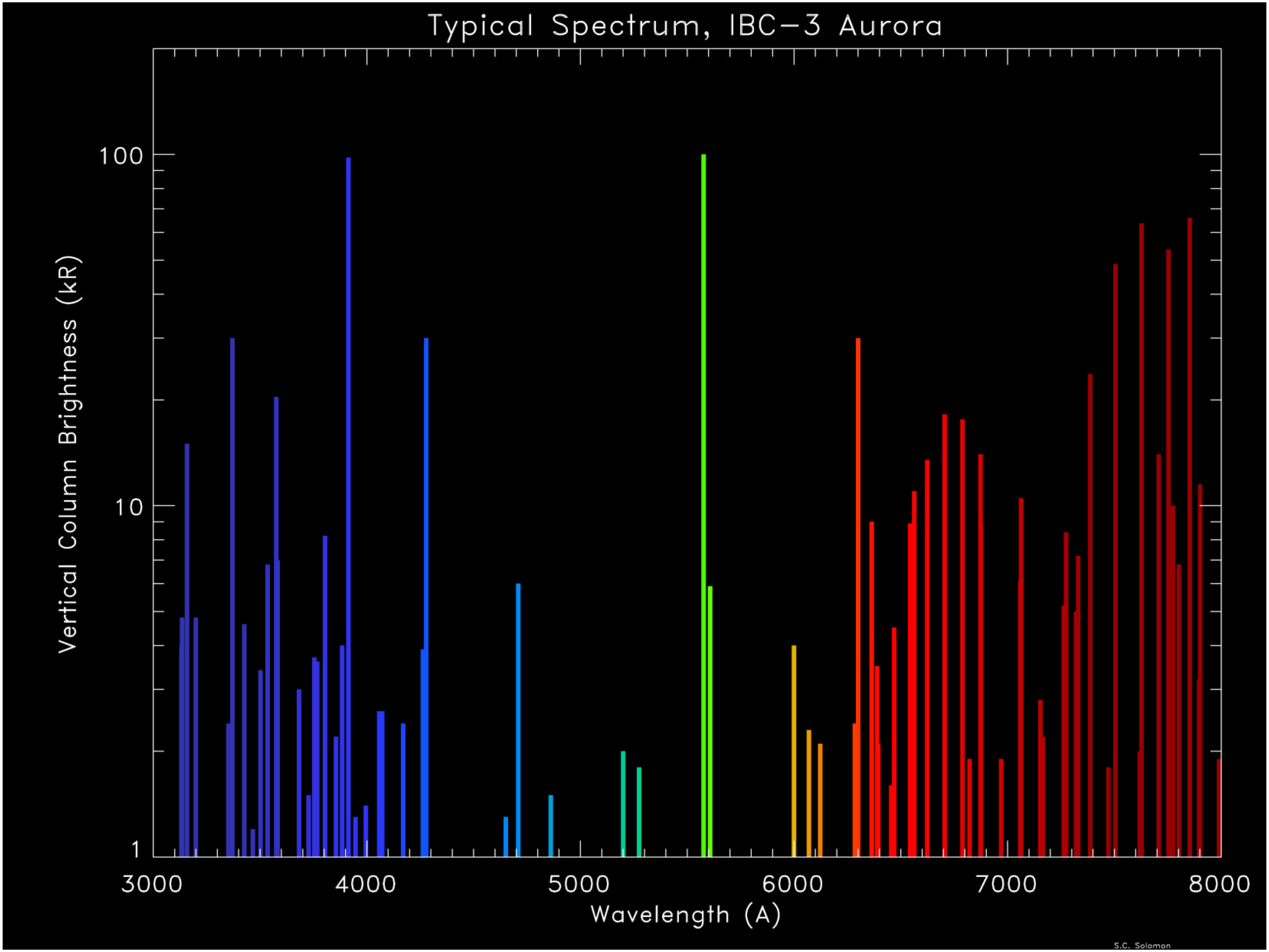
$e^* + N_2 \rightarrow e^* + N(^4S) + N(^2D)$ $\quad$ $N(^2D) \rightarrow N(^4S) + h\nu$ $\quad$ (5200Å) $_{\tau\sim 100{,}000s}$

$N(^2D) + O \rightarrow N(^4S) + O$

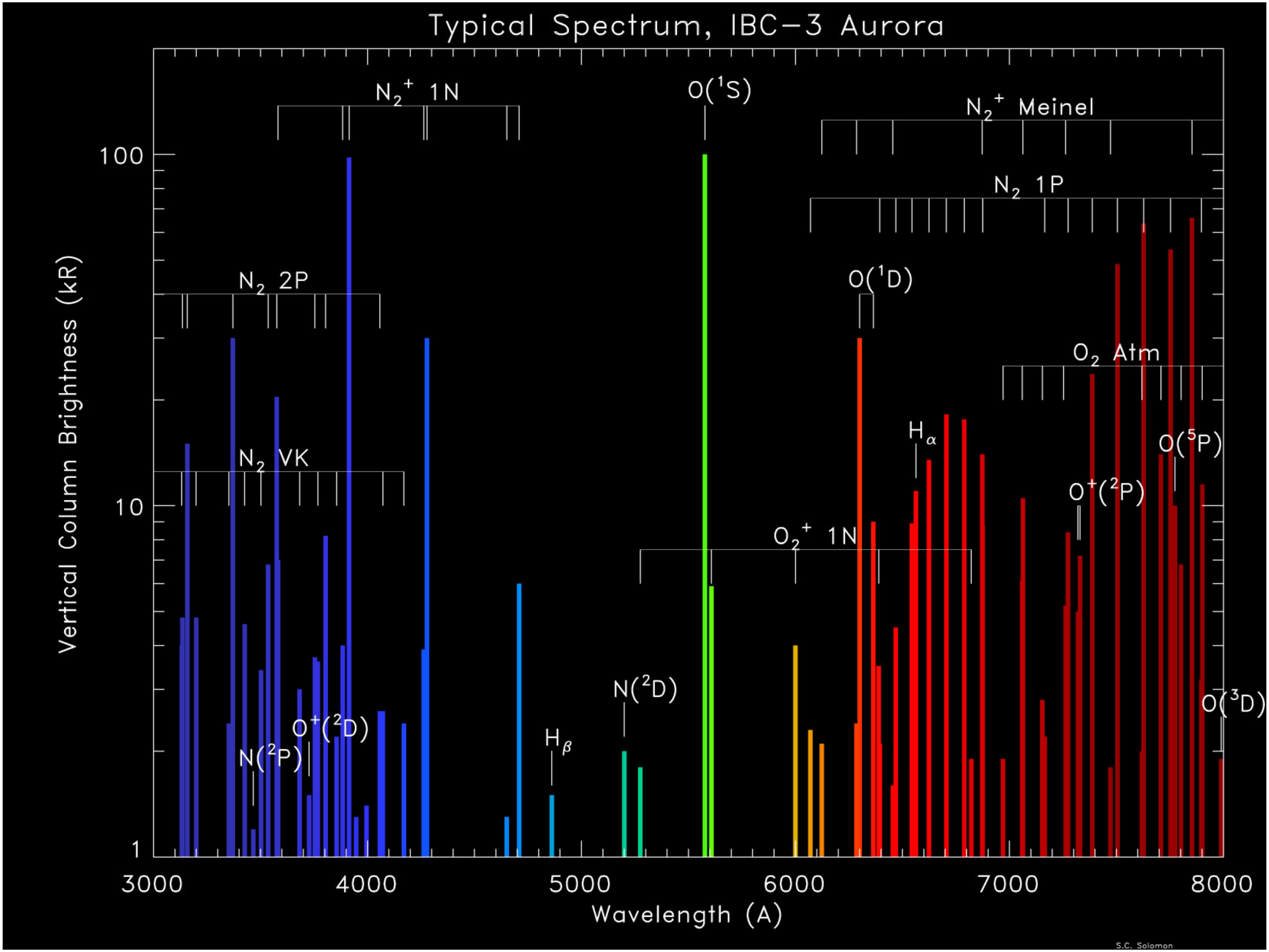
$NO^+ + e^- \rightarrow O + N(^2D)$ $\quad$ $N(^2D) \rightarrow N(^4S) + h\nu$ $\quad$ (5200Å) $_{\tau\sim 100{,}000s}$

$N(^2D) + O \rightarrow N(^4S) + O$


Typical Spectrum, IBC−3 Aurora
Vertical Column Brightness (kR)
0
20
40
60
80
100
120
3000
4000
5000
6000
7000
8000
Wavelength (A)
S.C. Solomon

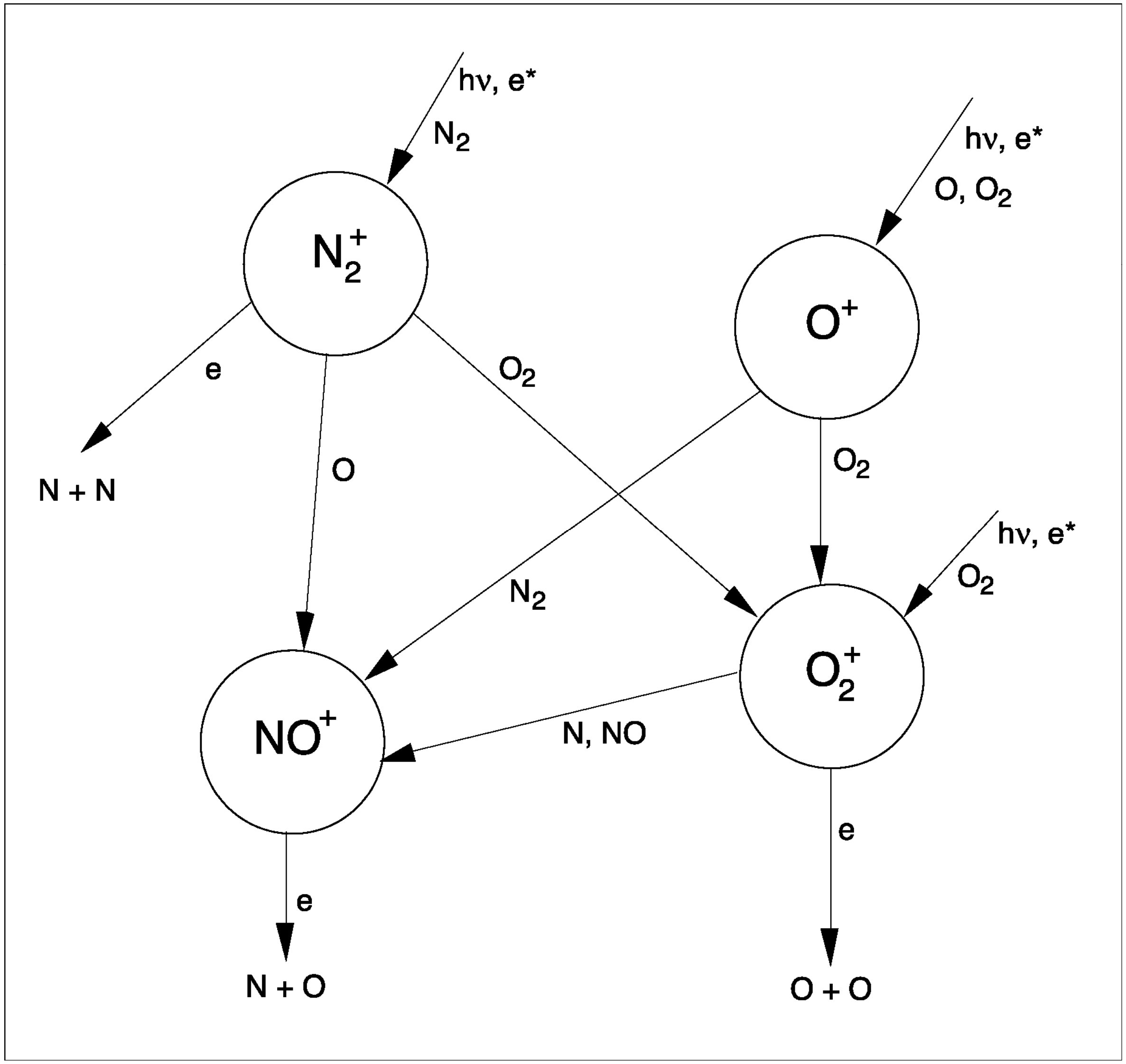


Typical Spectrum, IBC-3 Aurora
Vertical Column Brightness (kR)
100
10
1
3000
4000
5000
6000
7000
8000
Wavelength (A)
S.C. Solomon



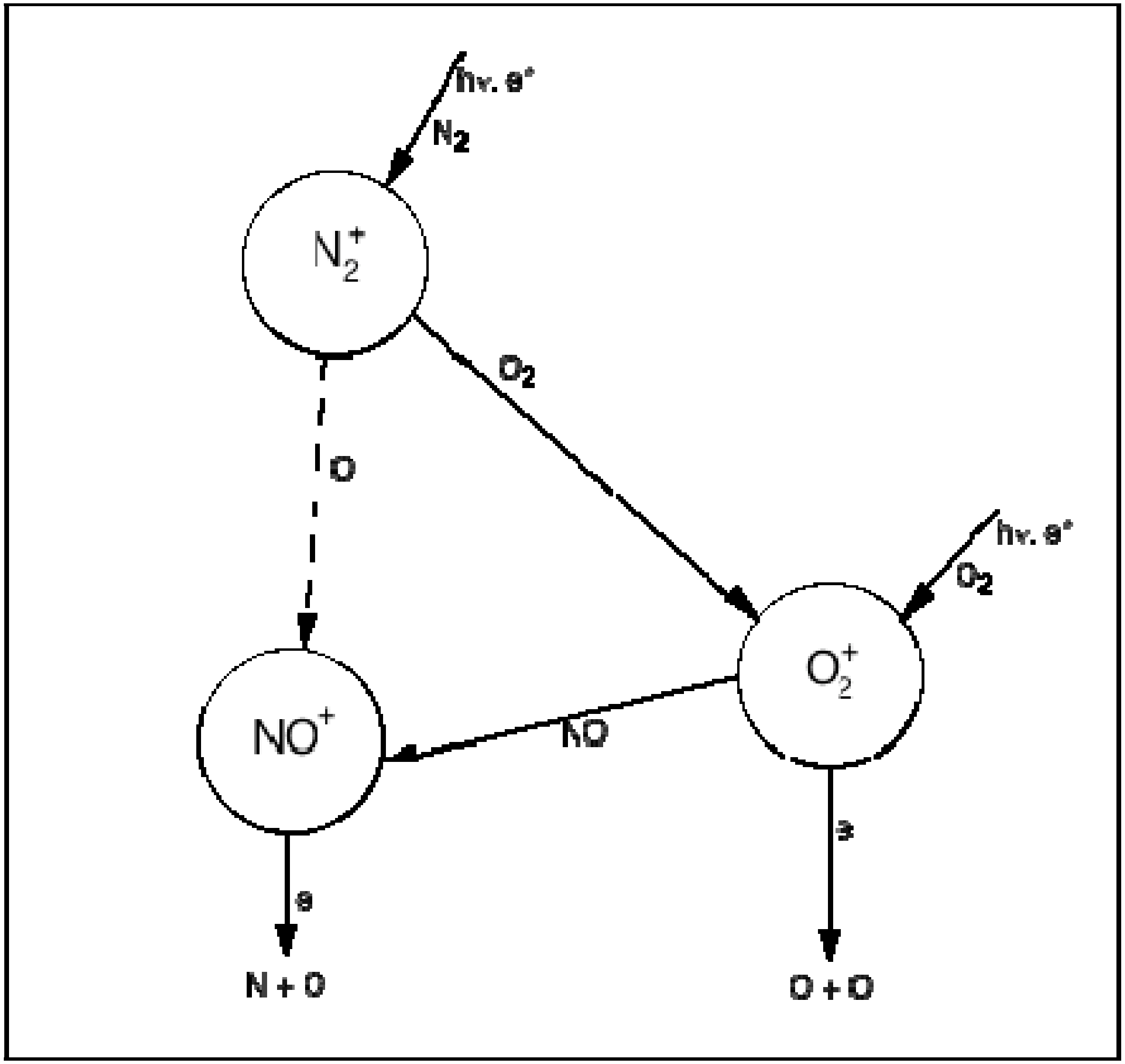
Typical Spectrum, IBC-3 Aurora
N_2^+ 1N
O(^{1}S)
N_2^+ Meinel
N_2 1P
N_2 2P
O(^{1}D)
O_2 Atm
H_α
O(^{5}P)
N_2 VK
O$^+$(^{2}P)
O_2^+ 1N
N(^{2}D)
O(^{3}D)
O$^+$(^{2}D)
H_β
N(^{2}P)
100
10
1
3000
4000
5000
6000
7000
8000
Vertical Column Brightness (kR)
Wavelength (A)
S.C. Solomon

Simplified Schematic of Ion-Neutral Chemistry

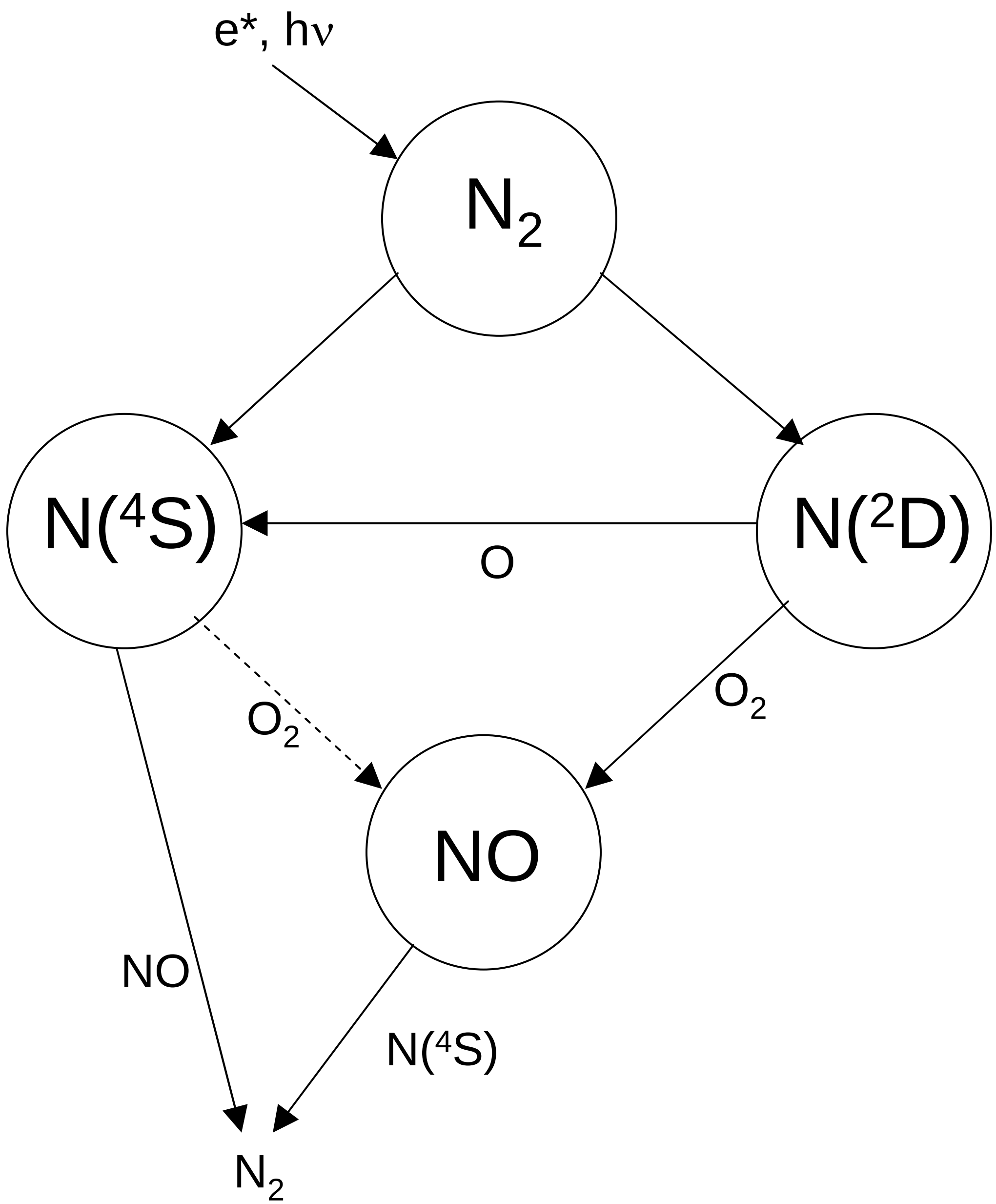


Ionization leads inexorably to dissociation

Simplified Schematic of E-region Ion-Neutral Chemistry

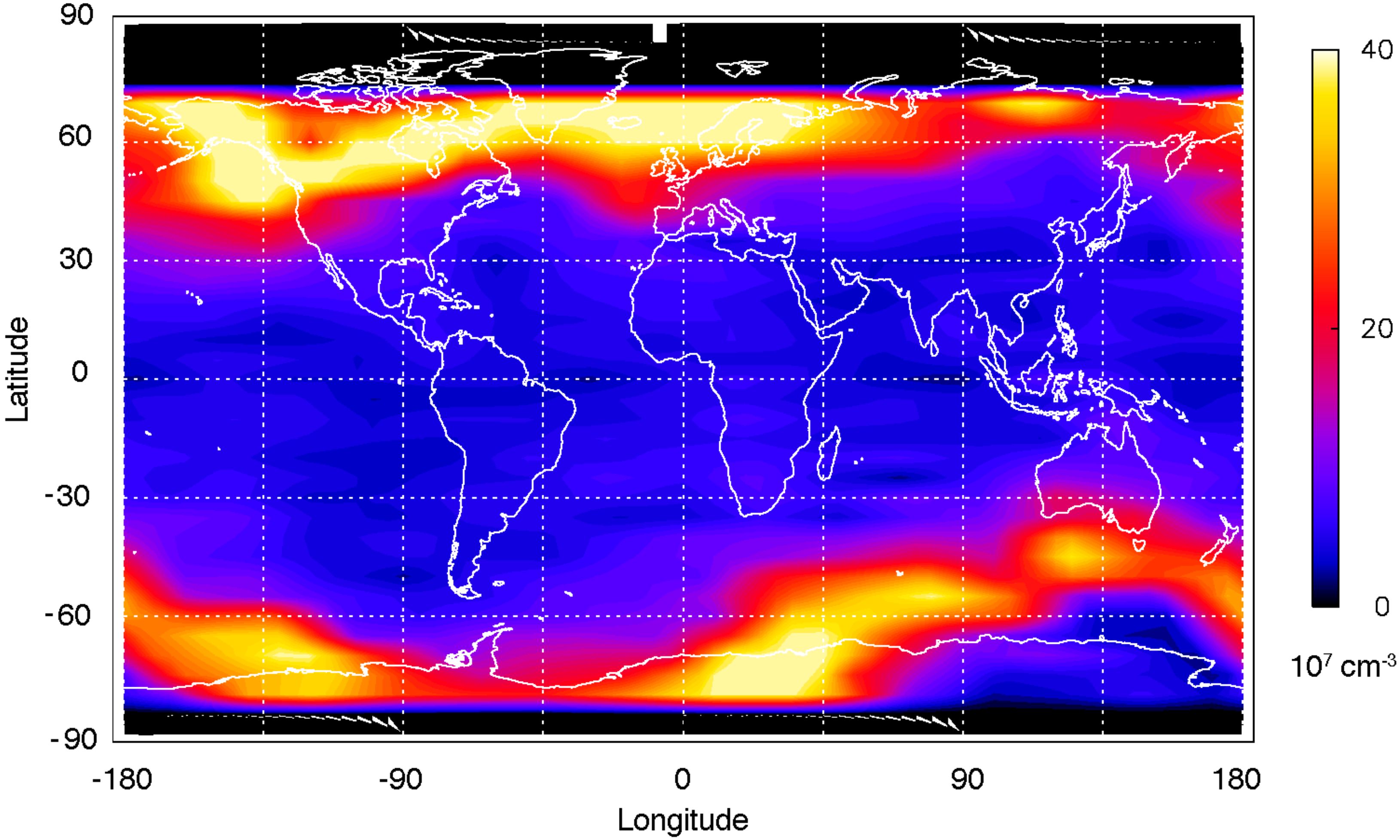


Simplified Schematic of Odd-Nitrogen Chemistry



Measurements of Nitric Oxide by SNOE

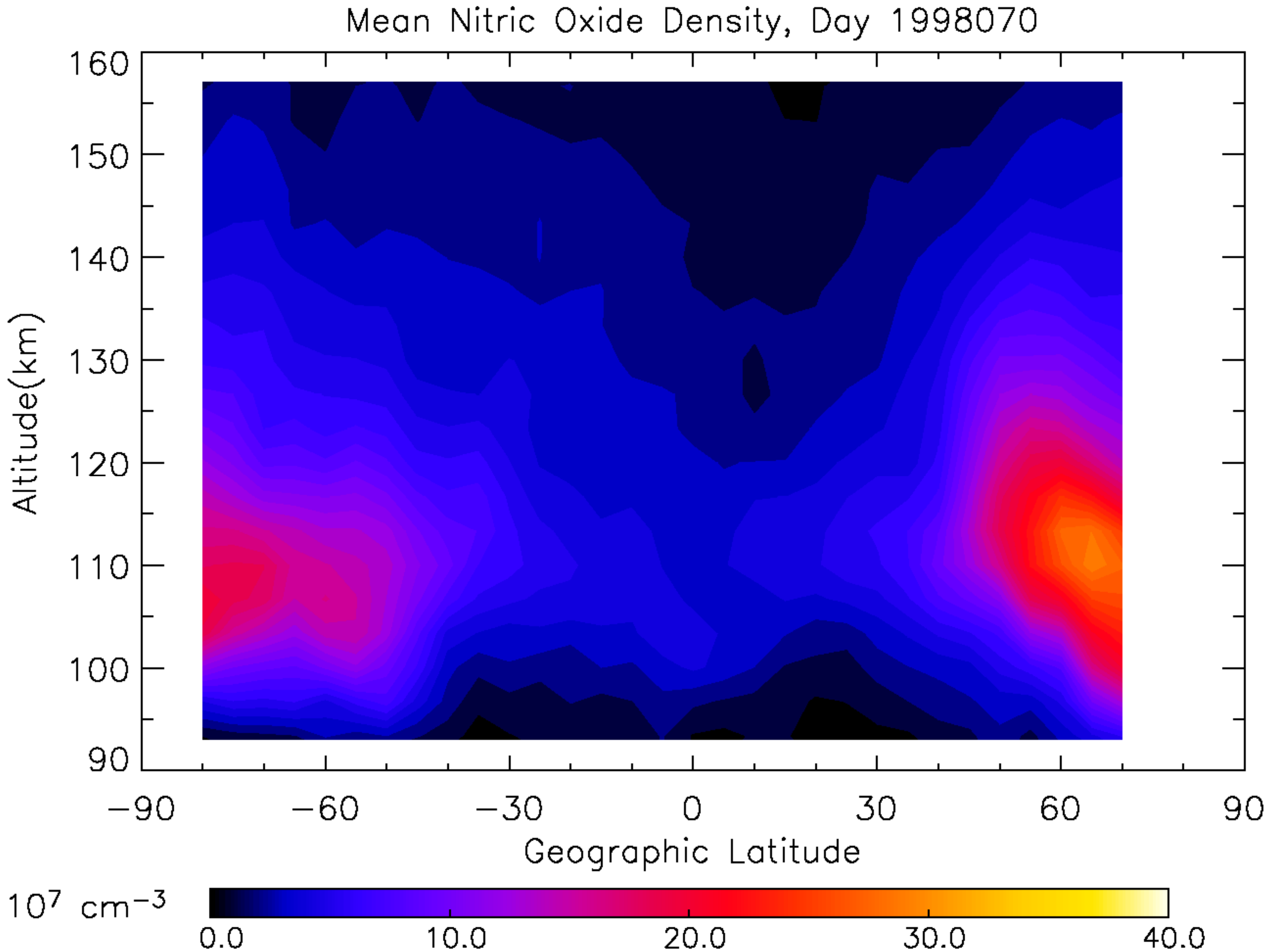
SNOE measured thermospheric nitric oxide using γ-band fluorescence method.
Measurement constrained to sunlit locations (i.e., can't measure at winter pole)
Altitude range 90–170 km; best quality data in range 100–150 km



Thermospheric NO Peak Density at 107 km, Day 1998 070

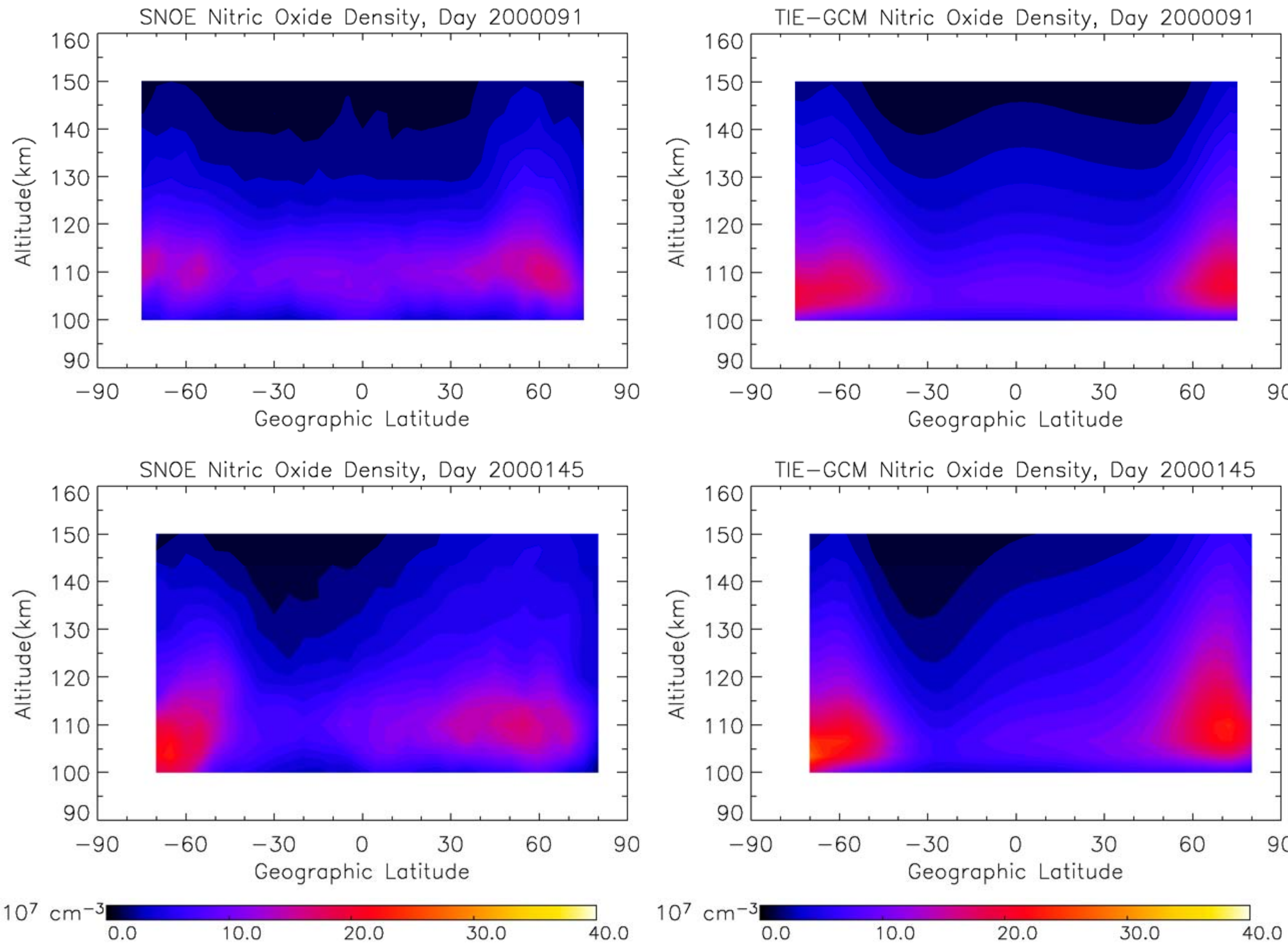
Measurements of Nitric Oxide by SNOE

Daily mean data at ~11 AM local solar time (15 orbits) averaged over all longitudes



Comparison of SNOE NO to TIE-GCM 1.8 Calculations

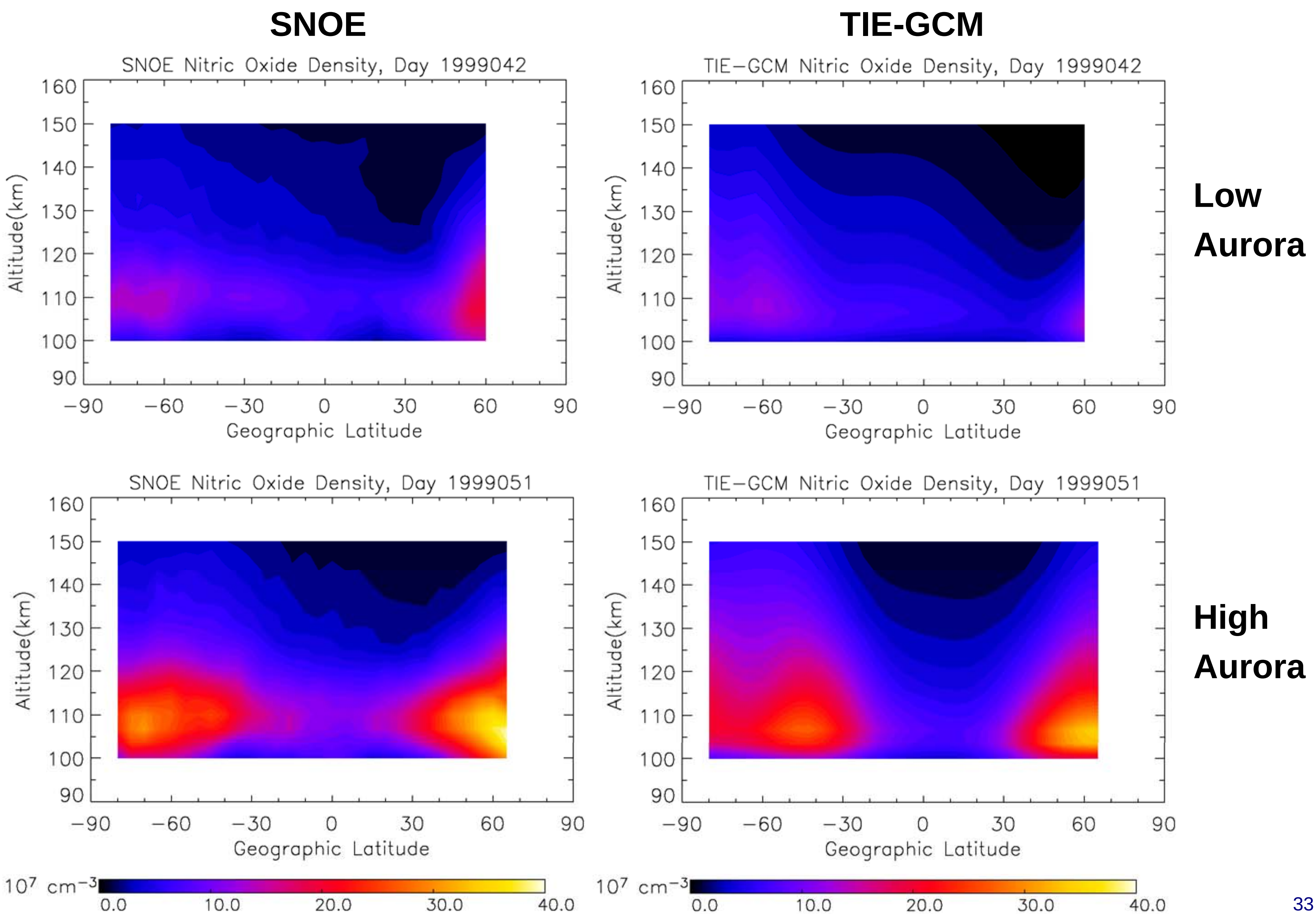
SNOE **TIE-GCM**



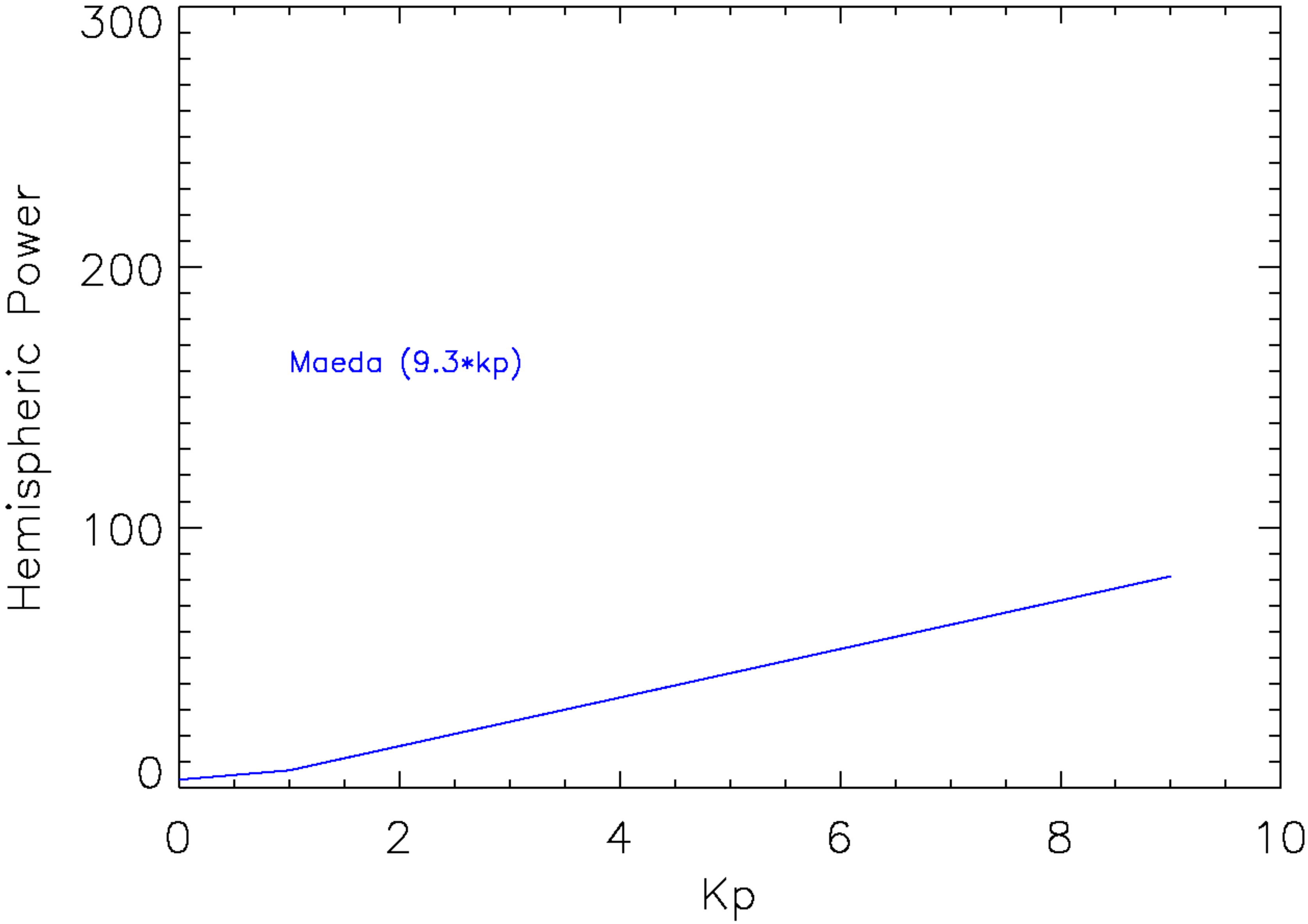
Equinox

Solstice

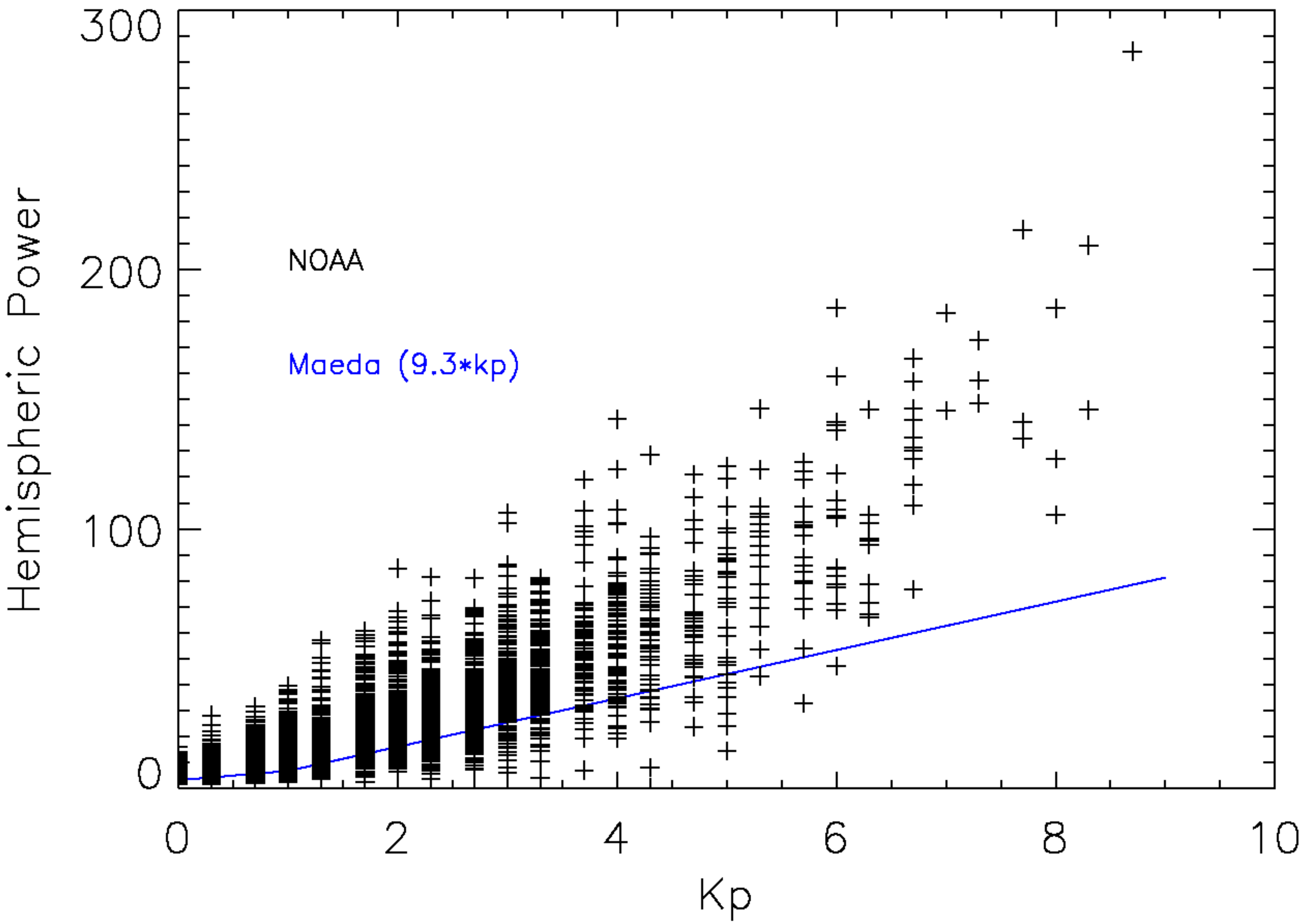
Comparison of SNOE NO to TIE-GCM 1.8 Calculations



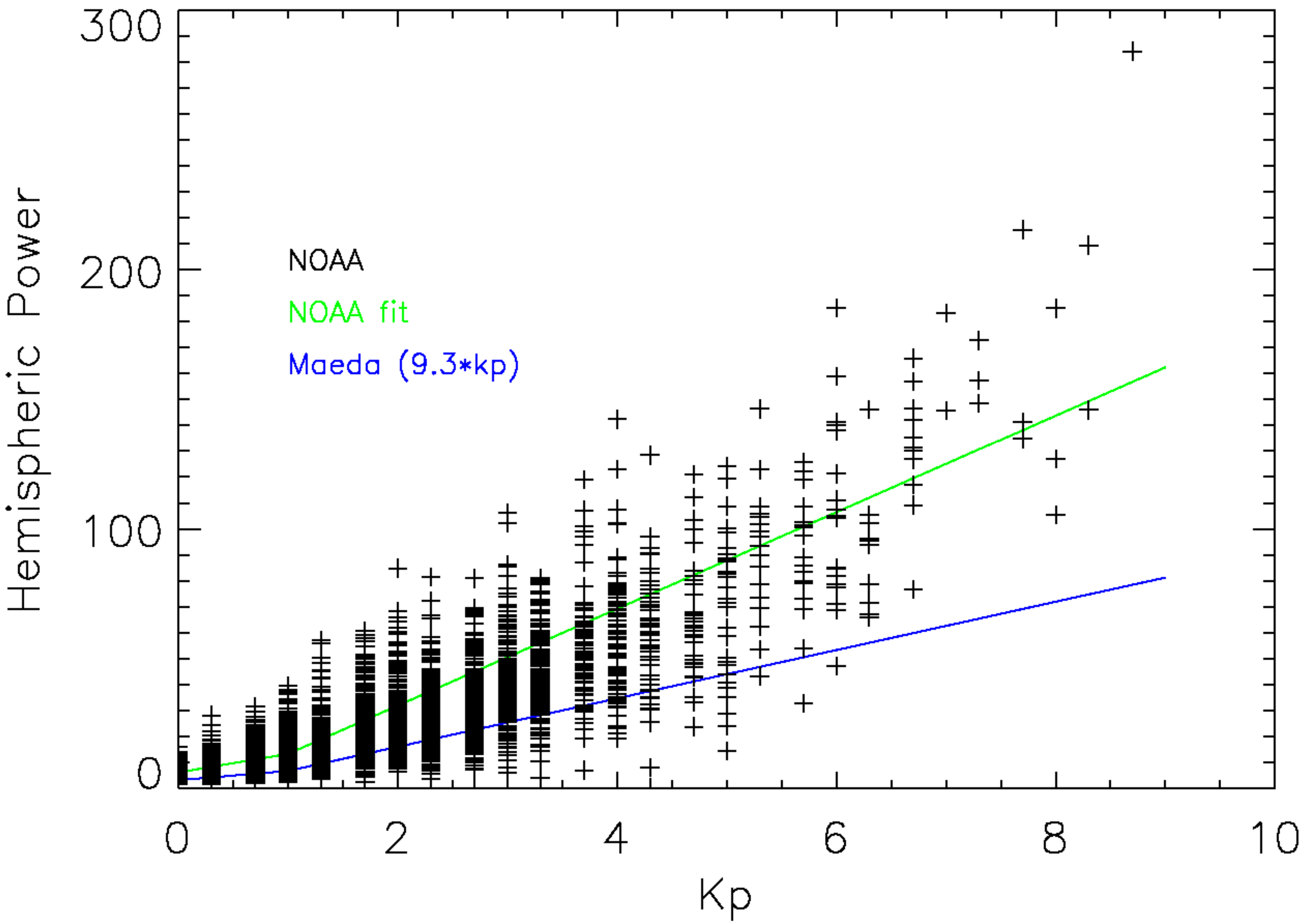
The 80's View — Linear Fit to NOAA/DMSP Particle Data



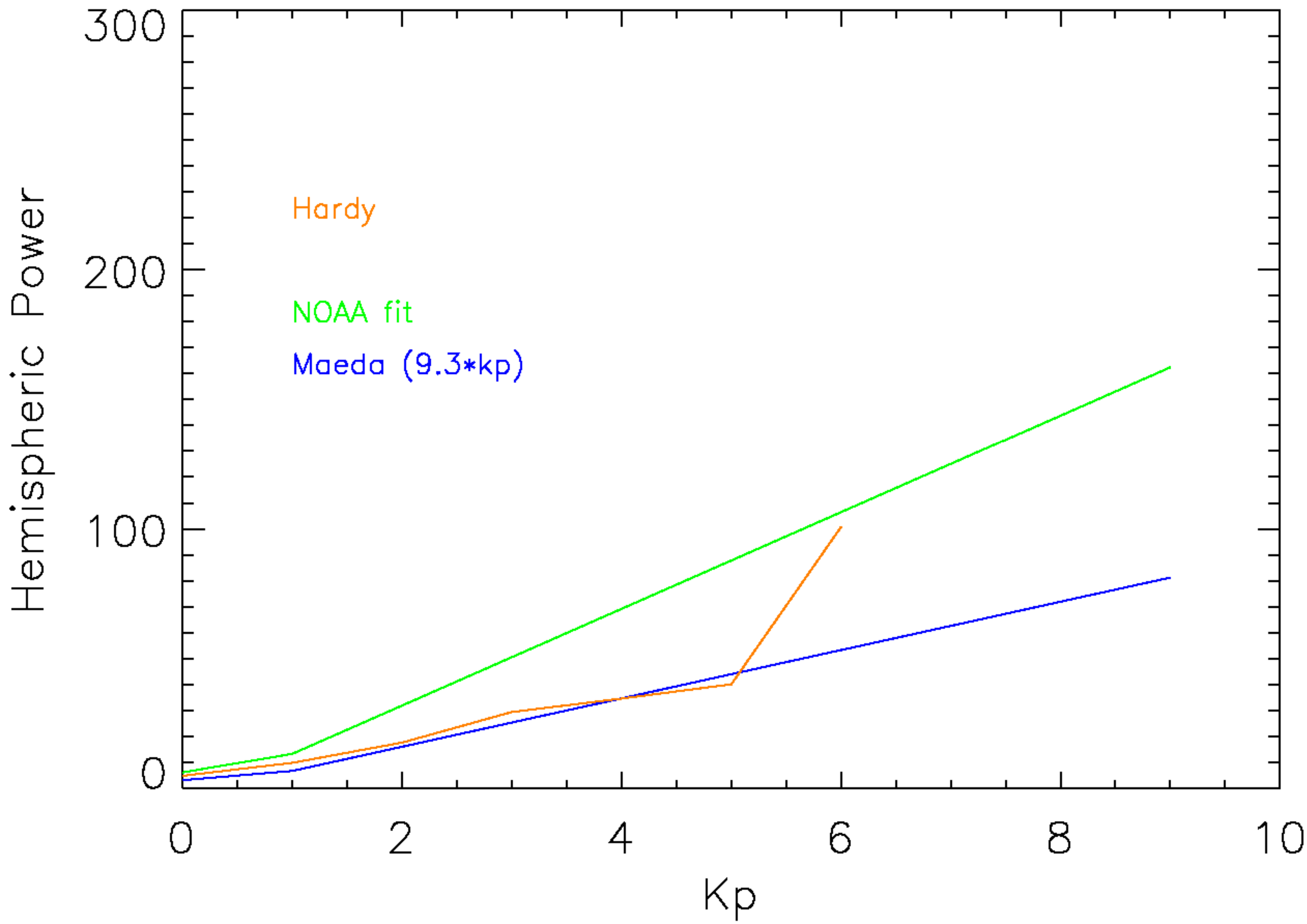
...But More Recent NOAA/DMSP HP Estimates are Higher



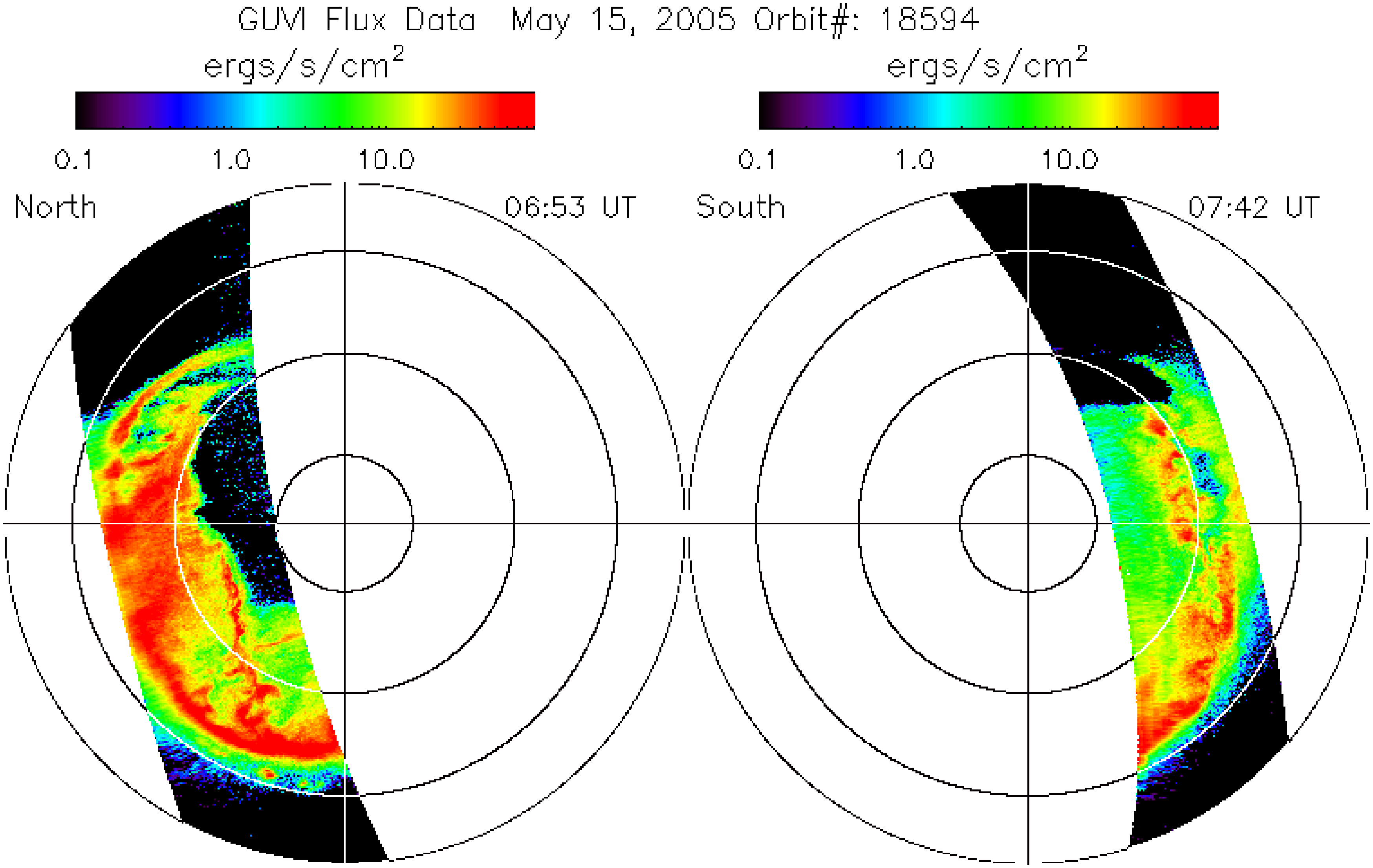
Fit to Current HP Estimates is Approximately 2 x Maeda



Comparison to HP Integrated over the "Hardy Oval"

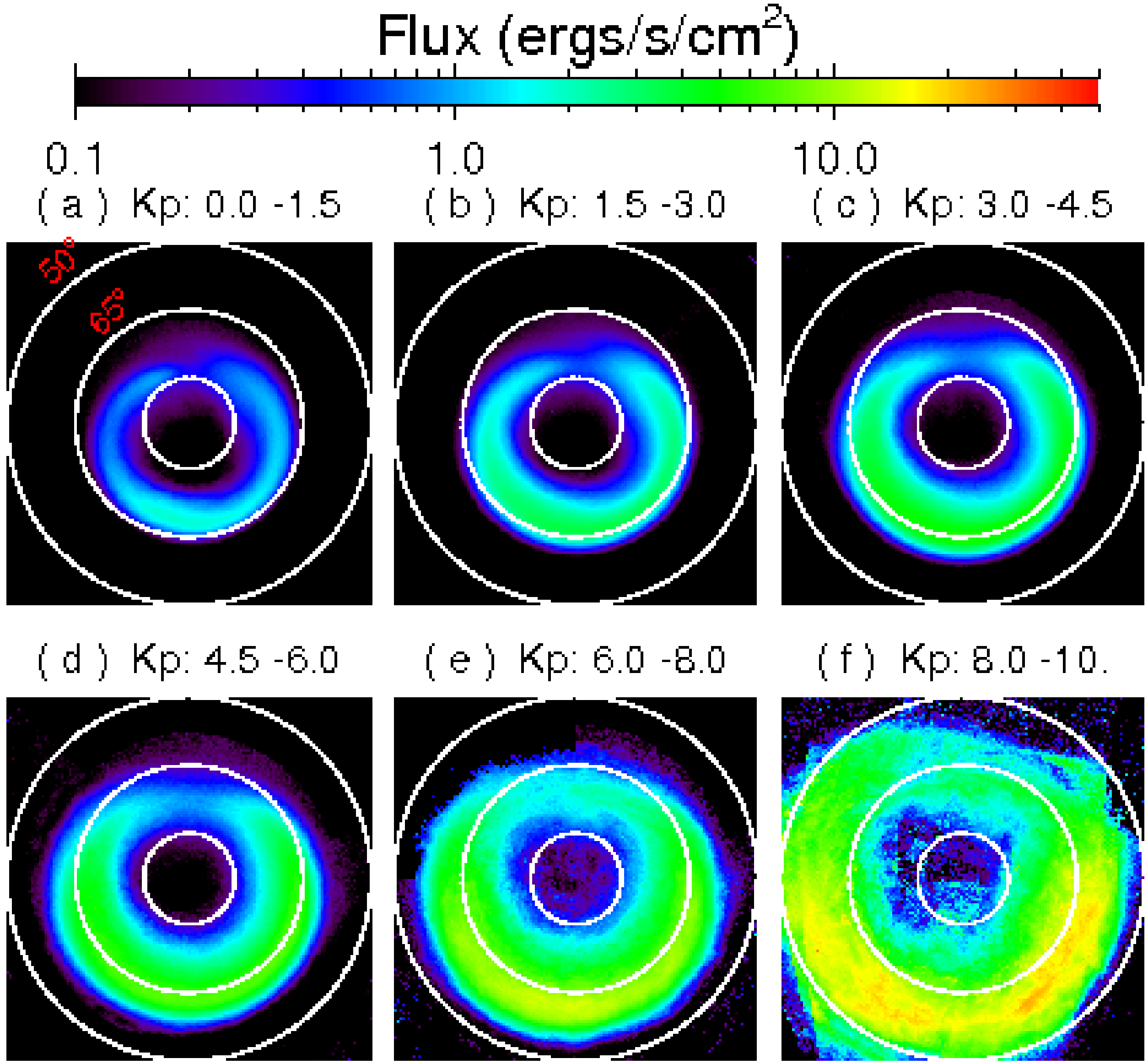


Auroral Measurements by the TIMED Global Ultraviolet Imager (GUVI)

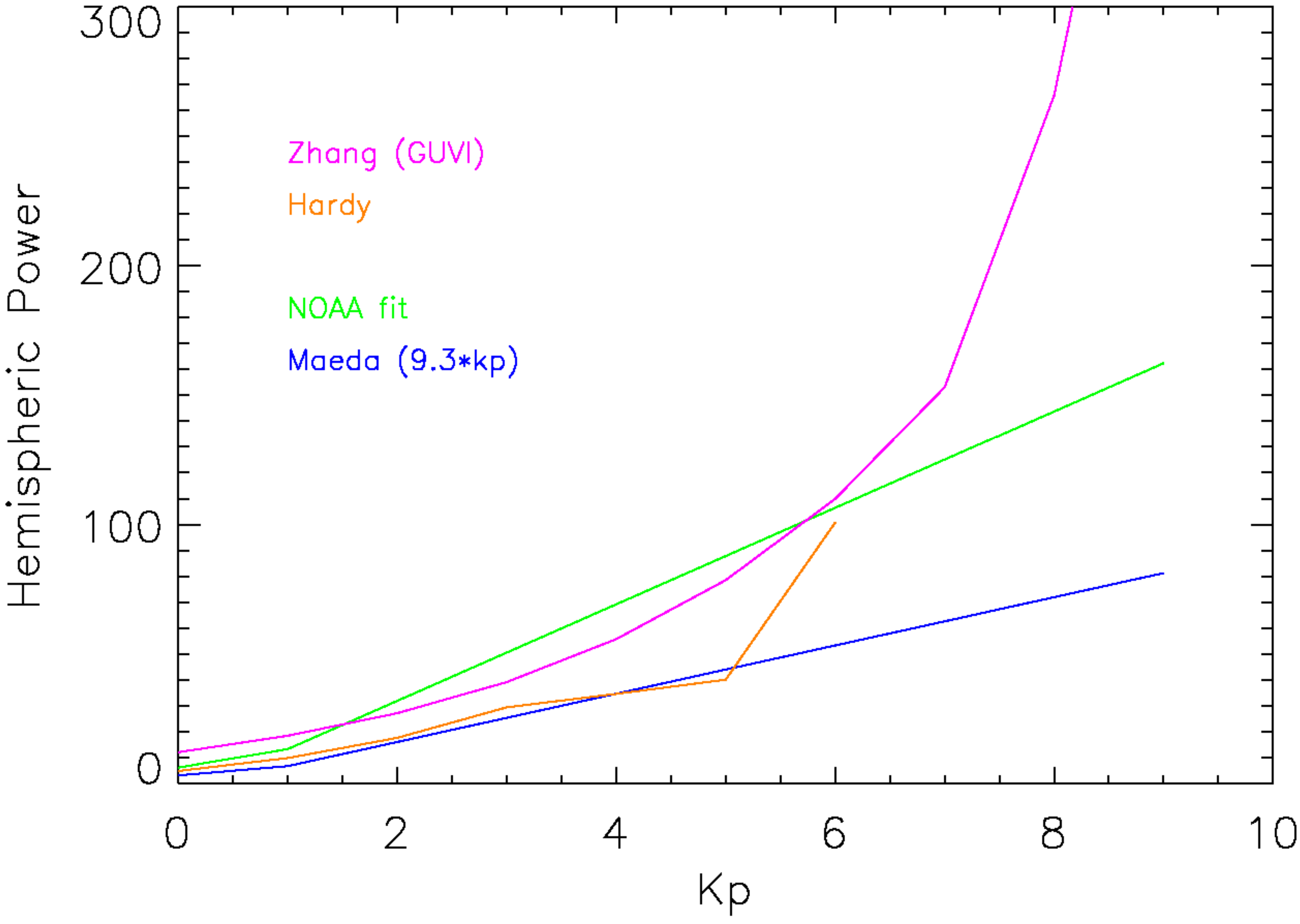


GUVI Empirical Auroral Oval

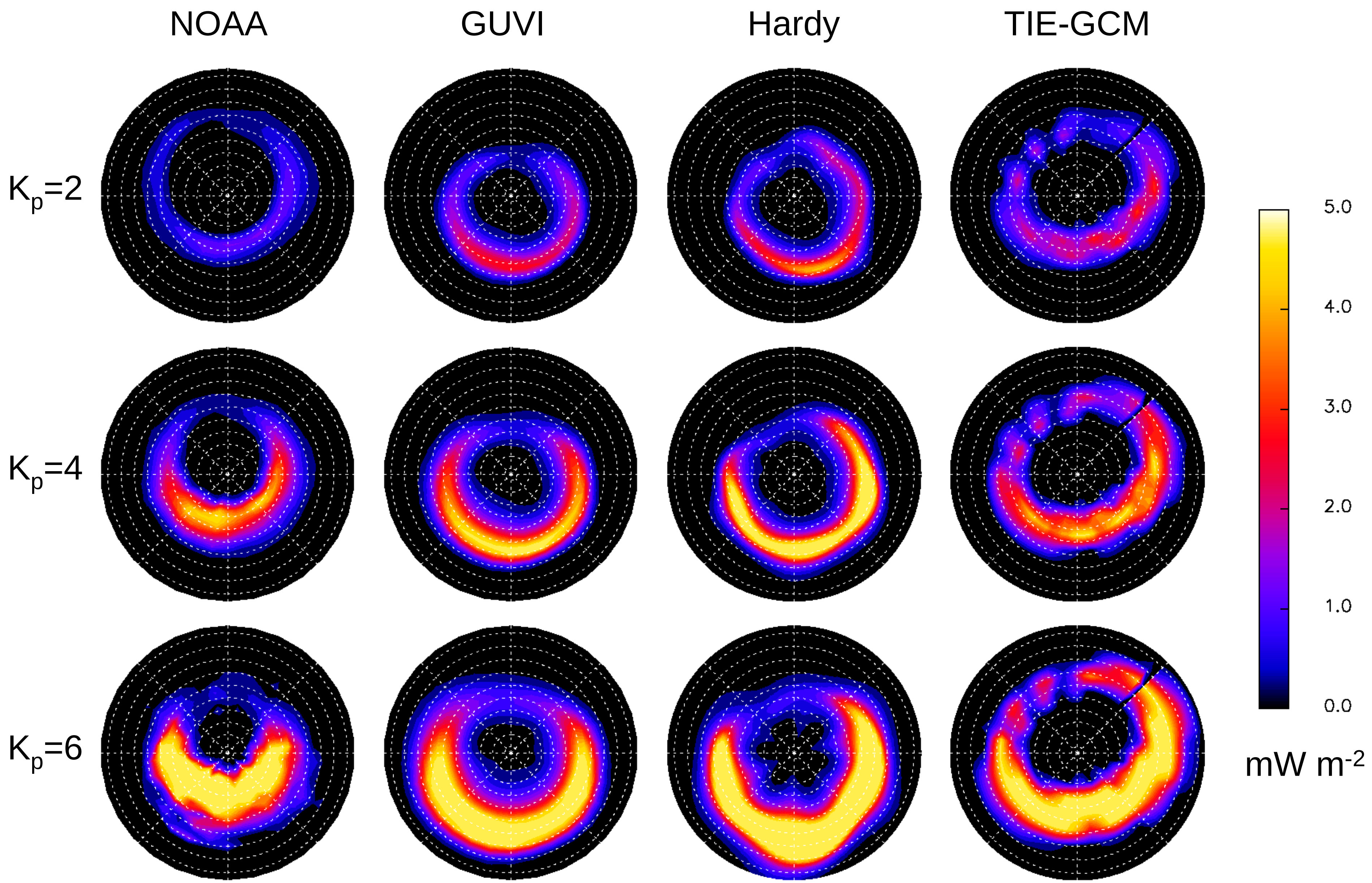
(ongoing work by Yongliang Zhang, Wenbin Wang, Xiaoli Luan)



Comparison to New Estimates from TIMED/GUVI



Morphology of Some Empirical Auroral Ovals



Nitric Oxide in NCAR General Circulation Models

Where we are:

— Believe that we have a realistic representation of auroral distribution and HP
...also now parameterized using solar wind / IMF input

— But TIE-GCM v. 1.93 still doesn't produce quite enough nitric oxide
...especially during high auroral activity

— Still get reasonable agreement with SNOE general morphology
...including latitudinal, seasonal, and solar cycle dependence

— Also get good agreement with SABER cooling rate observations
...see talk by Mlynczak et al., later this afternoon.